Nottingham. AVELINE.

71 N.E.

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE

GEOLOGY OF THE COUNTRY AROUND NOTTINGHAM.

QUARTER SHEET 71 N.E., WITH SMALL PORTIONS OF 71 S.E. & S.W.

BY

W. TALBOT AVELINE, F.G.S.

SECOND EDITION.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.

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1880.

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PREFACE.

It is more than 20 years since the geological survey of the district delineated on the Geological Survey map Quarter Sheet 71 N.E. was made, and, as the explanation of the geology of that map has been for some time out of print, it has been thought advisable to reprint it with additions.

During the 20 years that have gone by, much additional geological evidence has come to light. New railways have been made, in the cuttings of which fine and interesting sections have been exposed, quarries and brickyards have been extended, and many new coal-pits sunk.

It was chiefly on account of the new Collieries that I visited the district again in 1878, in order to have the position of the pits inserted on the map, and to learn the evidence shown by these sinkings, so as to bring up the geological information to the latest date.*

There has also been another source of fresh information, which has tended to modify the geological work on the east side of Nottingham. When this part was first surveyed, it was chiefly covered with fields and small gardens, guarded by high fences and locked gates, while a few roads and brickyards afforded the only sections from which to make out the geological structure of this area, which has since been transformed into a busy town. It was from the exposures of the strata made while digging the foundations of the houses, constructing the deep sewers, forming the new streets, and cutting down the roads, that a more accurate knowledge of the geology of that area was acquired. But the information thus opened out would have been entirely lost had it not been for a gentleman of Nottingham, Mr. James Shipman, who, for upwards of 10 years, spent most of his leisure hours in watching the excavations, and carefully noting every change of the strata exposed, marking the directions of the Faults and the amount of their throw, the thickness and dip of the beds, &c., &c.

* A Revised Edition of Geological map 71 N.E. is now published.

Some of the results of these observations were given in a paper read by him before the Nottingham Naturalists' Society,* and in communications to the Geological Magazine, one of which he wrote in conjunction with Mr. E. Wilson, F.G.S. Mr. Shipman kindly allowed me to make use of the results of his long and diligent labours, and I only regret that the small scale of the 1-inch map will not allow of full justice being done to his work.

Twenty years ago little had been written on the geology of Nottinghamshire, and when I was stationed at Nottingham I knew only one gentleman† who took any interest in the subject. But of late years many good papers have been written by Messrs. Shipman, Wilson, Irving, and others, and through the impetus given by the South Kensington Local examinations, there appears to be a large school of young geologists rising up, much to the credit of Nottingham.

My best thanks are due to the Managers of the various Collieries whose names I have mentioned in this Memoir, for the kind and ready manner in which they have afforded me information.

W. T. A.

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* Published in the Midland Naturalist, vol. i. pages 18 and 30.

† The late Dr. Thomas Wilson, the father of Mr. E. Wilson, F.G.S.

GEOLOGY

OF THE

COUNTRY AROUND NOTTINGHAM.

INTRODUCTION.

THE part of the country of which this Map illustrates the geology comprises an area of 168 square miles in the south of Nottinghamshire. The town of Nottingham is situated on the south side of the district, and Southwell in the north-east. The river Trent enters this country a little south of Nottingham, and flows through it in a north-east direction. A small river, called the Leen, rises near Newstead Abbey, and flowing south joins the Trent near Nottingham. Both these rivers have many tributaries in small brooks.

The features of this country are various. There is the broad alluvial valley of the Trent, with an undulating country to the south-east, rising from the plain in a steep escarpment or cliff. The highest point of this side of the district is Dewberry Hill, 271 feet above the sea, and nearly 200 feet above the river. On the north-west side of the Trent Valley the country between Nottingham and Southwell rises with a gradual slope much cut up by many deep valleys. It may be described as a ridge of ground extending in a north-east direction from Nottingham, broken through by the brook called Dover Beck, and again by the river Greet. This ridge has a steep escarpment facing the north-west, and a gentle slope to the south-east. It is this slope that is cut up by deep valleys, the brooks in which rise near the top of the ridge and flow to the Trent. The highest point of this ridge is at the ancient camp on Cock-pit Hill, 521 feet above the level of the sea or about 440 feet above the Trent at Burton Joyce. The central part of the district forms a marked contrast to that which I have been describing. The land on either side of the Trent Valley forms a good soil and is much cultivated, and is besides well watered; while that part where stood the Forest of Sherwood has a barren, sandy, unprofitable soil, with few brooks. This partially cultivated country commences at Nottingham, and extends northward between the villages of Basford and Bulwell on the west, and Arnold on the east to Arnold Forest; and there spreading out includes all the high Forest-land, its greatest width being at the north border, where it extends from Farnsfield to Robin Hood's Hill, a distance of 9 miles, and a spur of this high

land extends south from Robin Hood's Hill for about three miles This Forest-land is an undulating country, with an average height of about 400 feet above the sea, the highest point being Robin Hood's Hill, 660 feet high. The land of the Forest in a general way rises gradually from the east, but descends sharply into the low ground at its western border. Standing on the top of the escarpment over the river Leen at any spot between Papplewick and Bulwell, and facing the west, you look down upon what appears to be a plain, out of which rise the ridge of Annesley Park, Hemps Hill, and the small rounded hills near Nuthall and Strelley, and the distant slopes of Wollaton Park; but it will be found on descending into this district that, besides minor undulations, the ground gradually rises to the west till another sharp descent is reached. The land of this sloping country (I do not include the Annesley and the other hills) has a good arable soil, though in places light, and it is well watered by many streams flowing eastward into the Leen. From this country we descend to an area of another kind, which stretches far away beyond the limits of our district, but runs into the brook valleys just within it, and also forms a long inlet reaching to the Leen at Radford, being low and wet ground between the higher and drier lands of Wollaton Park on the south, and Bilborough on the north. This land has a wet, poor, and heavy soil, but is generally well wooded.

When the Map is studied with the help of this Memoir it will be seen how much the geology accords with the features I have described, and how geological changes have influenced them.

The formations coloured on the Map are as follows:*—

Alluvium and Gravel of the Trent.

New Red Sandstone
- Keuper
  - Red Marl and White Sandstone.
  - Porous Sandstones and Marl (Waterstones).
  - Conglomerate.
- Bunter
  - Pebble and Conglomerate beds.
  - Lower Soft Red and Mottled Sandstone.

Permian
- Red Marl and Sandstone.
- Magnesian Limestone.
- Shales.
- Breccia.

Coal-measures.

Besides these formations there are superficial deposits of Drift-clay, gravel, and sand lying indiscriminately on all the above rocks; sometimes thickly and sometimes thinly, and these are not distinguished on the map by any colour.

The thicker black lines on the part coloured as Coal-measures indicate the out-crops of beds of coal. The white lines are Faults or dislocations. The arrows point to the direction in which the

* Section No. 1, Sheet 61, of the Geological Survey, shows the relative positions of these formations.

beds are inclined, and the numbers by the side of the arrows show the amount of the dip in degrees. The cross-marks show where the beds are horizontal.

COAL-MEASURES.

The Coal-field of Nottinghamshire is a continuation of those of south Yorkshire* and Derbyshire, but it is only the south-eastern extremity of these great united Coal-fields that comes within the area now under notice.

It will be seen by referring to the Map that the parts coloured as Coal-measures occupy only small portions of it, the largest being in the valley through which runs the Nottingham Canal, and the others occurring in the valleys along the western border; these are all inlets from the more extensive Coal-field to the west, and there is also an inlier exposed in the valley north of Bilborough. These areas coloured as Coal-measures do not, however, represent the whole extent of the workable Coal-field of this district, but only those parts where the rocks pertaining to the Coal-measures lie uncovered by any other formation, the Coal-measures in many places being reached by pits sunk through the overlying Permian and Triassic rocks.

As in other districts the coal-formation is here an accumulation of beds of sandstone, shale, clay, coal, and ironstone, alternating with each other. There are many beds of coal in this field lying at intervals below each other, and separated by sandstones, shales, &c., but it is only a few of these beds that are thick or good enough to be worked profitably. In order to give some idea of the beds and their succession, the names of the different coals, their average thicknesses and distances apart, and to point out the workable ones, I give a vertical section of the Derbyshire and Nottinghamshire Coal-field, and as the highest beds are in this district, the section represents the succession which would be met with, if a deep pit were sunk through these Coal-measures. Clunch usually means tough clay or shale: Bind, shaly clay, often blue; and Bat, carbonaceous shale.

Vertical Section of the Nottingham and Derbyshire Coalfield.

The first part (to the Top Hard Coal) from a Pit at Cinderhill.

No.	Description of Strata.	Thickness.	Depth.
		FT. IN.	FT. IN.
1	Limestone (Magnesian) - - -	5 4	—
2	Light-blue and brown Stone in beds	6 3	11 7
3	Blue Stone - - -	8 5	20 0
4	Dark-pink Bind	3 8	23 8
5	Dark-grey Stone - - -	0 4	24 0
6	Red Stone with pebbles -	1 0	25 0

* A Memoir on the South Yorkshire Coalfield is now published.

No.	Description of Strata.	Thickness.	Depth.
		FT. IN.	FT. IN.
7	Clunch (usually tough clay or shale)	1 9	26 9
8	Bind	19 0	45 9
9	Ironstone	0 3	46 0
10	Soft Clunch	5 0	51 0
11	Black Shale or Bind	2 7	53 7
12	Clunch	6 8	60 3
13	Bind, with bands of Ironstone	40 4	100 7
14	Chillery Coal	0 7½	101 2½
15	Light and dark Clunch	6 0	107 2½
16	Bind	20 9	127 11½
17	Ironstone	0 2½	128 2
18	Bind	14 7	142 9
19	Soft Coal	1 1½	143 10½
20	Shale Bind and Clunch	20 2	164 0½
21	Soft Coal	2 4½	166 5
22	Clunch and Bind, with Bat and Shale	18 10	185 3
23	Soft Coal	1 0	186 3
24	Clunch and Bind	1 0	187 3
25	Soft Coal	1 7½	188 10½
26	Clunch and Stone	5	198 3½
27	Bind, Clunch, Stone, and Bat, with a little Coal and Ironstone	81 8½	280 0
28	Coal	3 6½	283 6½
29	Dark Clunch, with Bat and Ironstone	20 8	304 2½
30	Coal	0 7	304 9½
31	Shaly Bind	10 1	314 10½
22	Soft Coal	2 4	317 2½
33	Shale and Bind	36 2	353 4½
34	Soft Coal	3 4	356 8½
35	Dark Clunch, with impressions	3 11	360 7½
36	Soft Coal	1 3	361 10½
37	Clunch and Bind	45 3	407 1½
38	Coal	1 5	438 1½
39	Black Shale and Bind	29 7	438 1½
40	Soft Coal	2 5	440 6½
41	Shale Clunch, &c.	68 7	509 1½
42	Coal	3 9	512 10½
43	Shale and Bind and a few small beds of Ironstone	82 3	595 1½
44	Coal (hard)	2 2⅓	597 4
45	Clunch, Bind, and Shale	50 0	647 4
46	MAIN COAL (TOP HARD)	8 2	655 6

This last coal is generally known by the name of the Top Hard Coal, and is in this pit divided thus:—

	FT.	IN.
Soft Coal	1	1
Clunch	0	5
Soft Coal	1	5
Clunch	0	1
Best Roof	1	2
RIFLER COAL	1	4
Hard Coal	2	0½
Soft Coal	0	7¾
	8	2¼

In another pit near Nuthall the divisions of the same coal are :—

	FT.	IN.
Soft Coal	1	1
Bat	0	3¼
Soft Coal	1	5
Clunch	1	2
Soft Coal	1	1
RIFLER COAL	0	9
Soft Coal	0	4½
Best hard Coal	1	5
Soft Coal	1	2½
	8	8¼

Below the Top Hard Coal the following is a general section :—

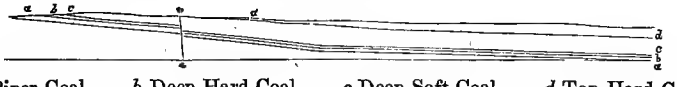
—	Thickness.		Depth below Top Hard Coal.	
	FT.	IN.	FT.	IN.
Clunch or Fire-clay	6	0	—	
Sandstone	14	0	—	
Coal	1	0	21	0
Clunch, Sandstone, and Bind, with Ironstone	41	0	—	
Coal	2	0	64	0
Bat, Clunch, and Bind, with Ironstone	34	0	—	
Coal called DUNSIL	3	3	101	3
Clunch and Bind	32	0	—	
Coal	1	4	134	7
Black Bat	0	5	—	
Inferior Coal alternating with Clunch	16	0	—	
Grey Stone	9	0	—	
Dark-blue Bind	15	0	—	
Coal	2	4	177	4
Clunch	0	6	—	
Stony Bind	16	6	—	
Bind, Clunch, and Bat	26	0	—	
Coal	1	10	222	2
Clunch, Rock, and Bind	40	0	—	
Coal	1	7	263	9
Clunch and Bind, with Ironstone	50	0	—	
Coal	3	0	316	9
Clunch, Rock, and Bind, with Ironstone	78	0	—	
Coal	0	8	395	5
Clunch	3	0	—	
Bind with Ironstone	25	2	—	
Coal	0	10	424	5
Clunch and Bind	11	0	—	
Coal	0	10	436	3
Bat, Clunch, and Bind	9	9	—	
Coal (probably the ELL COAL)	1	0	447	0
Bind and Rock	54	0	—	
The MAIN or DEEP SOFT COAL	3	0	504	0
Bat	1	0	—	
Dark Clunch and Fire-clay	12	6	—	
Bind and Rock	6	10	—	
The DEEP HARD COAL	3	6	527	10

The following section gives the chief coals below the Deep Hard Coal:—

—	Thickness.		Depth below Top Hard Coal.	
	FT.	IN.	FT.	IN.
Clunch, Bind, &c.	66	0	—	
Piper Coal	5	0	71	0
Bind, Clunch, and other strata	138	0	—	
Furnace Coal	4	0	213	0
Clunch, Bind, &c.	108	0	—	
Yard Coal	3	0	324	0
Clunch, Bind, &c.	30	0	—	
Black Shale Coal	5	4	359	4
Clunch, Bind, &c.	459	0	—	
Kilburn Coal	3	6	811	10
Depth of Kilburn Coal below Top Hard Coal	—		1,339	8

Of all the coals of the above sections the only beds that are or have been worked in this district are the "Top Hard" or "Rifler," "Waterloo," "Main Soft," "Lower Hard," and "Piper Coals." No pit has been sunk below the last. These beds crop to the surface in this district and are marked on the Map. The "Piper" Coal, the lowest, and therefore the most westerly (the beds having an easterly dip), comes to the surface between Swanser Field and Trowell Moor. The "Main Soft" and "Lower Hard" Coals crop out very near together on the east side of Trowell Moor and can be traced in a N.N.W. direction. The "Waterloo," a coal of not much importance, and not now worked, crosses the canal a little to the west of the Engine-pit Colliery. The crop of the "Top Hard Coal" crosses the land a little to the west of Wollaton Bridge. A horizontal section taken from west to east along the line of canal or with the dip of the beds would appear somewhat in the manner represented in the wood-cut beneath.

Fig. 1.



a Piper Coal. *b* Deep Hard Coal. *c* Deep Soft Coal. *d* Top Hard Coal.
* Fault.

Few of these coal-crops can now be accurately traced, because all near the surface has long since been removed, and in many cases all signs of the old workings are obliterated. The greater part of the Top Hard Coal has been taken away from the southern portion of this field. To judge from the many abandoned coal-pits there cannot be much of this coal left south of the turnpike road from Nottingham to Watnall, but north of a line drawn eastward from Watnall Chaworth no pits that I am aware of (in 1861) have been sunk; however, no doubt as the coal is worked out in the south, pits will be advanced northwards, and the country surrounding the villages of Linby and Hucknall Torkard will become a Coal-field.*

* This is now the case, and Collieries are in active work at Hucknall Torkard, Linby, Newstead, and Annesley (1880).

Several Faults or dislocations affect the beds of this Coal-field. One of these, striking N.N.W. and S.S.E., crosses on the west side of the Engine-pit Colliery, and throws the beds down 14 yards on the east. This Fault is marked on the map, and it may be seen that it does not affect the overlying formations. There are other Faults that do not appear on the surface, but are found in the underground workings; one of these, commencing near Basford, runs under Horseing Dale Farm and Nuthall Park, and throws the strata down to the northwards 40 yards. There is another parallel to this that runs by Aspley Hall; this is also a down-throw to the north, but I could not obtain any very reliable information respecting it, the pits having been so long deserted, and as far as the "Top Hard" Coal is concerned, it is now of no importance, that coal having been worked out.

Another large and important Fault has been discovered in the workings of the Cinderhill Colliery. It runs from near Bagnall through Nuthall Temple to Kimberley; it has in the Coal-measures a down-throw south of 80 yards, with a hade of 35 degrees. This Fault, where known on the surface, is said to only affect the strata overlying the Coal-measures for 12 yards. It is this Fault that was marked on the first edition of the map as running from Hempshill by Bagnall to the north of Basford.

Another underground Fault strikes from the large one from near Upper Hempshill in a N.N.W. direction, passing by the east side of the upcast pit of the Cinderhill Colliery. This Fault has a down-throw to the west. There are two other Faults found in the Newcastle Colliery workings, one running under the "Two Mile House," in a W.N.W. and E.S.E. direction, with a down-throw to the north of 20 yards. The other running N.W. and S.E. by the west side of the Newcastle pit with a down-throw to the east of 20 yards.

In the workings of the Collieries in the northern part of the district it does not appear that any large Faults have yet been met with, though probably they may be found beneath where the overlying strata have been much disturbed by being thrown into sharp anticlinals as shown on the map. As yet the coal has been found to lie, little disturbed, with a gentle dip to the east.

In the Annesley Colliery several small Faults have been met with, but it is impossible to lay them down on a map on so small a scale as one inch to a mile, and they do not appear to affect the overlying formations. The chief of these Faults have a N.E. and S.W. direction running from the pits to Annesley Hall; other faults are at right-angles to these; the throws are from 1 to 19 yards.

There are not many places where the strata of the Coal-measures are exposed at the surface, but they may be seen in the cuttings of the Nottingham Canal, in one of which there occur beds of sandstone and shale and two beds of coal. By the side of the canal, west of Swanser Field, there are Coal-measure sandstones of a red colour. Also where the Coal-measures are exposed by the denudation of the Magnesian Limestone south-west

of Cinderhill, there occur sandstones, shales, and a bed of coal. At Kimberley, bricks are made from Coal-measure shales.

The principal Collieries that were, or had been lately at work in this district in 1858 were,—

1st. The Cinderhill Colliery, where, in one of the pits commenced in the Magnesian Limestone, the Top Hard or Rifler Coal has been worked, and is 660 feet deep. A second pit close beside the last has been sunk to a depth of 1,479 feet to the "Main Soft" Coal, but the particulars of this I could not obtain.* On Hempshill there is the upcast pit to the Cinderhill Colliery, a distance of nearly half a mile. The depth of this pit, commenced in the Permian Marls, to the Top Hard Coal, is 700 feet.

2nd. Newcastle Colliery near Basford, a pit commenced in the Magnesian Limestone and sunk to a depth of 400 feet, to the Top Hard Coal.

3rd. The Watnall Colliery, a pit about 370 feet deep, also to the Top Hard Coal.

4th. The Kimberley Colliery, where in a new pit they found the Top Hard Coal at 324 feet, the Main Soft Coal at 807 feet, and the Main Hard Coal at 852 feet from the surface. This pit was commenced in the Magnesian Limestone, of which there is about 26 feet.

5th. The Babbington Colliery, near Strelley, a pit commenced in the Coal-measures below the outcrop of the "Top Hard" Coal, nearly 370 feet deep, to the Main Soft Coal.

These Collieries, with the exception of the Watnall Colliery, were the property of the late Thomas North, Esq., to whom and to his Chief Colliery Engineer, the late Mr. Woodhouse, of Derby, I was indebted for the above information.

The Collieries named below were the property of Lord Middleton from whose Colliery Agent, Mr. Taylor, I obtained the following information.

6th. Radford Colliery, a pit 240 feet deep to the "Top Hard" or "Rifler" Coal.

7th. Catstone Hill Colliery, a pit commenced in the Coal-measures to the west of the out-crop of the "Top Hard" Coal, struck the "Waterloo" Coal at 72 feet, the "Main Soft" Coal at 330 feet, the "Main Hard" Coal at 372 feet, and the "Piper" Coal at 414 feet.

8th. At the Old Engine-pit Colliery, near Trowell Moor, the "Main Soft" Coal was found at 255 feet.

The following coal-pits have been sunk since the first edition of this Memoir was written (1861).

Wollaton Colliery pits, commenced in the Coal-measures near the out-crop of the "Top Hard" Coal, reached the "Waterloo" Coal at a depth of 120 feet, the "Main Soft" Coal at 535 feet, and the "Bottom Hard" Coal at 575 feet. Mr. W. Dawson, manager.

* These Collieries have very lately become the property of the Cinderhill Colliery Company, and their manager, Mr. G. Fowler, informed me that in this sinking the large Fault mentioned on page 7 was passed through, so that the depth of this pit is not a true measure of the thickness of the strata.

Pit sunk by Messrs. Barber and Walker between Nuthall and Watnall, commenced in the Magnesian Limestone sunk to the "Top Hard" Coal.

Watnall New Colliery commenced in the Permian Marls and sunk to the "Top Hard" Coal, which was reached at a depth of 963 feet. Mr. Robert Harrison, manager.

The Hucknall Torkard Colliery Company's No. 1 pits, situated one mile S.S.W. of Hucknall Torkard church, commenced in the Magnesian Limestone found the "Top Hard" Coal at a depth of 1,163 feet. And at their Colliery, No 2, on the east side of the village of Hucknall Torkard, the pits were commenced on the junction of the Permian Red Marls and the Magnesian Limestone; the depth to the "Top Hard" Coal is 1,230 feet. Mr. J. E. Ellis, manager.

Linby Colliery. These pits were commenced in the Magnesian Limestone, and the "Top Hard" Coal was reached at 1,287 feet. Mr. Henry Lewis, manager.

Newstead Colliery, commenced in the Lower Soft Red Sandstone of the Bunter were sunk to the "Top Hard" Coal, which was reached at 1,368 feet. Mr. Stevenson, manager.

Annesley Colliery. These pits were commenced in the Permian Marl, and reached the "Top Hard" Coal at 1,415 feet, and the "Dunshill" Coal below at 1,485 feet. Mr. Henry Lewis, manager.

The Bestwood Colliery. These pits are the most easterly that have been sunk in this district. They were commenced in the Pebble Beds of the Bunter, $1\frac{3}{4}$ miles N.N.E. of Bulwell, and sunk to a depth of 1,231 feet or the "Top Hard" Coal. The thickness of strata overlying the Coal-measures is 144 feet. The manager of this Colliery, from whom I received this information, is Mr. Howard Allport.

The Clifton Colliery, though not actually within the district under notice, is so close to its southern edge, on the west bank of the Trent, that it may be added to the list. The pits were commenced in the Alluvium of the river and at a depth of 24 feet the lower beds of the Bunter were apparently reached and the Coal-measures at 156 feet. The "Top Hard" Coal was found at 224 feet. The "Dunsill" Coal at 279 feet. The "Waterloo" Coal at 306 feet. The "Deep Soft" Coal at 714 feet. The "Deep Hard" Coal at 755 feet, and the "Piper" Coal at 800 feet. So that the whole of the coals that crop to the surface in this district were penetrated in the pits of this Colliery. I am indebted to Mr. Henry Fisher, manager, for the above and other information regarding this Colliery.

An interesting question, both scientifically and economically, is the extent of the Coal-bearing strata eastward below the overlying secondary rocks, and the probable depth at which workable coal may be met with. The question formed a prominent one in the inquiry of the Royal Commissioners* in 1871, when this

* See Report of the Royal Commissioners on Coal.

district was specially alluded to and the evidence and opinions of several scientific and practical men were taken and afterwards published in their Report.

It was the opinion of Professor Ramsay, Mr. Green, and others, that the coal-bearing strata of which the South Yorkshire, Derbyshire, and Nottingham Coal-fields form a part, lay in a basin-shaped form, like those of South Wales and the Forest of Dean. That the beds after dipping eastward for some miles from their westerly outcrop gradually flattened and then rose with a westerly dip till they struck against the overlying formation.

The effect of this would be, that if a pit or boring were sunk many miles eastward of the Nottinghamshire Coal-fields, after the secondary rocks were penetrated, instead of meeting with Coal-measure strata, (which would be the case if the pit or boring was sunk only a short distance from the field), strata older than the Coal-measures might be found lying immediately below the secondary rocks. Also that within a limited distance coal-beds would be met with at a less depth from the surface than if the measures continued with the same easterly dip which they have at their outcrop.

Since the Royal Commissioners' Report was issued farther research has tended to confirm the opinions with regard to the Coal-measure basin. It has been found that the beds do flatten from their westerly outcrop eastward. On the western side of the district the beds dip from 4° to 5° eastward, but where the most easterly pits are sunk the dip of the beds is not more than 2° eastward, if so much. If the dip of the "Top Hard" Coal continued at the same angle as at its outcrop it would not have been reached at the Bestwood Colliery at a less depth than 2,100 feet instead of 1,231 feet from the surface. Another confirmation of the basin-shaped theory of these Coal-measures is the turning round of the measures to the east at the southern side of the Coal-field. At the Clifton Colliery the "Top Hard" Coal was reached at a depth of only 224 feet from the surface. It is true that a Fault on the south side of the shaft throws down the measures 285 feet, but this does not affect the question. The inclination of the strata at the bottom of the shaft at Clifton Colliery is one in 20, or about 2° eastward.

In any trial for coal made eastward of the present Collieries the thickness of the formations overlying the Coal-measures will have to be taken into consideration, and, in the absence of any thinning out of the Triassic and Permian formations, the farther to the east the trial may be made the greater will be the thickness to be gone through. In a south and south-easterly direction the Magnesian Limestone *has* thinned away, for none was met with in the sinkings at the Clifton Colliery, nor was there any found in a boring made at Owthorpe. This boring was commenced in the Lias, and carried down into the Coal-measures. The Lias, together with the Rhœtic beds, was about 66 feet thick, and, as far as I can make out from the details of the boring furnished

to me, the Coal-measures were reached at a depth of between 1,069 feet and 1,083 feet. This would give for the Trias formations a thickness of over 1,000 feet. In the neighbourhood of Southwell, on the eastern side of our district (71 N.E.), the thickness of the Triassic rocks would not be so great. The thickness of strata from the top of the Waterstones to the base of the Lower Mottled Red Sandstone may be from 500 to 520 feet; but to this must be added 30 feet or 40 feet of Permian rock. Therefore in a shaft or boring sunk at Southwell, commencing in the Waterstones, Coal-measure strata may be expected at a less depth than 600 feet, or anywhere on the Keuper Marl at a less depth than 1,000 feet from the surface, and if the beds of the Carboniferous Series are becoming horizontal, no greater thickness of Coal-measure strata would probably have to be gone through to reach the "Top Hard" Coal than that at the Bestwood Collieries, which was 1,087 feet; moreover, if the beds were rising with a westerly dip, there would then be a less thickness.

A farther supposed confirmation of the theory of the uprise of the Carboniferous rocks is derived from the deep boring made at Scarle in Lincolnshire, about 26 miles in an E.N.E. direction from the Bestwood Colliery. This boring was commenced in the Blue Lias Limestone and carried down to a depth of 2,030 feet from the surface; of this 1,900 feet were through strata overlying the Carboniferous formation so that only 130 feet of Carboniferous rocks were penetrated. The first 118 feet of these Carboniferous rocks consisted of greyish earthy limestone and calcareous shale, below which there was one foot of greenish coarse grit, and breccia, and below this 10 feet of red marl or clays in which the boring was left off. From these details there is, apparently very little to indicate to what part of the Carboniferous series these beds belong, nor does the presence of a small bivalve shell, supposed to be a species of Anthracosia, throw much light on the subject, for this shell is found at several stages throughout the upper Carboniferous system. Professors Ramsay and Hull, who examined the cores, came to the conclusion that these Carboniferous beds were referable to the lower Yoredale series. This opinion was founded on their lithological character, which is that of an earthy limestone. It is right to say, however, that this opinion is not shared by many practical coal-miners, especially the Colliery Managers of Nottinghamshire. They maintain that beds of the same character are met with in the higher part of the Coal-measures. Mr. Howard Allport states that in sinking the Bestwood Pits the first stratum, found a short distance below the Magnesian Limestone, seemed to tally with the red clay or marl from the bottom of the Scarle boring. Of course, it is quite possible, even if the beds do rise with a westerly dip under the Triassic rocks, that they may, within a certain distance, roll over and again resume their easterly dip. As far as our immediate district is concerned, I think there is little doubt but that the "Top Hard" Coal may be reached at a workable

depth anywhere below the area occupied by Triassic rocks east of the present Collieries.*

PERMIAN.

There are three divisions of the Permian formation in this district. The first, at its base, is a bed of breccia. The second is the Magnesian Limestone. The third and uppermost division is a series of red marls and sandstones.

Breccia.

The lowest division, the breccia, is exposed in a cutting of the Erewash Valley Railway at Grives Wood. It is a calcareous breccia, containing pebbles of chert, quartz, and sandstone, some of the latter pebbles being red. It is only a few feet thick, and is here overlaid by the shales of the next division. This breccia is not continuous; it disappears southward, for in other sections† along the western border the Limestone, or second division, lies directly on the Coal-measures; but, on the southern edge, a thin bed of breccia may again be seen by the side of a pond at Old Park Farm. There may, however, be a doubt about this bed being precisely contemporaneous with that in the railway-cuttings. Fifteen feet of shale intervene between it and the limestone-bed, but here, lying between the breccia and the limestone, there are only three or four feet of yellow and red marly beds. This breccia, which is from one to two feet in thickness, is made up of pebbles of sandstone and marl, apparently derived from the Coal-measures, and a few quartz pebbles. It lies on light-yellow and pinkish sandy shale pertaining to the Coal-measures. There is another bed of yellow rock with quartz pebbles, seen in a railway-cutting south of Cinderhill, but there is not enough exposed to ascertain with certainty whether this bed is part of the Permian Rocks or belongs to the Coal-measures.

Since the first edition was written the new lines of railway of the Great Northern and the Midland in their cuttings at Kimberley have exposed the junction between the Coal-measures and the Permian, and the breccia is again seen. A fine section is exposed on the north side of the Midland line showing the Permian rocks resting unconformably on the Coal-measures. On the upturned edges of the Coal-measure shales and sandstone is a bed of breccia from 2½ to 3½ feet thick, above this 1½ foot of red shale, and above this 15 feet of thin shale and thin beds of limestone to the top of the bank.

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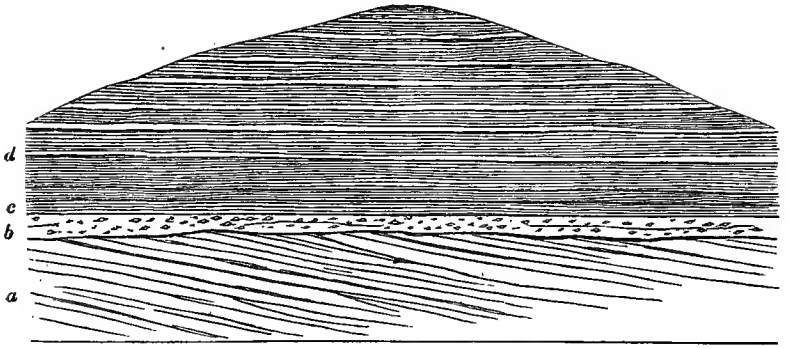
* When the Derbyshire and Nottinghamshire Coal-fields are geologically surveyed on the scale of six inches to the mile, a Memoir, like that on the South Yorkshire Coal-field will be written, when the question as to the extension of the Coal-bearing strata beneath the Secondary rocks, will be again gone into with greatly extended data.

† This refers to sections that were exposed in 1858.

Fig. 2.



a. Coal-measures. *b*. Permian Breccia. *c*. Red shales. *d*. Thin bedded blue and light brown shales and bands of limestone.

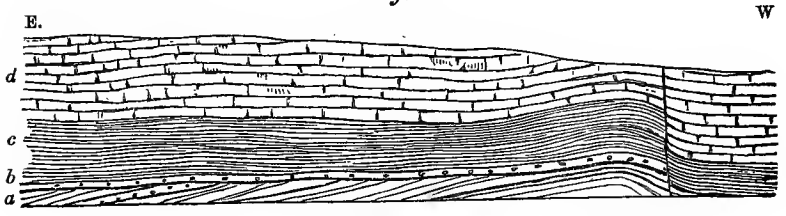
Farther east along the cutting the Coal-measures are brought up again by a Fault, and the Breccia is seen resting unconformably on them. The Coal-measures rise in an anticlinal, and the Breccia is well exposed dipping eastward below the shales that underlie the Magnesian Limestone. The breccia may be also seen in the cutting of the Great Northern Railway between the Kimberley station and a small bridge to the west. The strata are here much faulted and broken, but in a brick-yard on the west side of Kimberley 2 to 3 feet of breccia are seen resting on the upturned edges of the Coal-measures.

In the cutting of the Great Northern Railway, east of Kimberley station, a very fine section is exposed on the sides of the deep cutting. This has been described in a paper by Mr. E. Wilson, of Nottingham, read before the Geological Society of London,* and the woodcut, Fig. 3, is taken from part of his published section, showing the Magnesian Limestone with shales beneath, underlaid by the breccia, which rests unconformably on Coal-measures. Speaking of the breccia, Mr. Wilson says, "At the base of all comes a breccia varying in texture from a "fine siliceous sandstone or grit a few inches thick to a coarse "and massive brecciated rock 4 feet thick. Its contained "fragments are plainly seen to be largely derived from the fine "ferruginous red and yellow Coal-shales, the sandstones and "ironstones of the neighbourhood; there are also angular or sub-"angular fragments of slate, quartz, quartzite, &c. The frag-"ments are stuck in confusedly at all angles." Farther on Mr. Wilson says, "We find that the breccia rests in a series of very "gentle undulations on a planed-off surface of Coal-measure "shales, sandstones, &c. These latter beds dip in a north-"easterly direction at an angle of fully 15° (but as the railway "section is there running about N.E. by E. the full dip is not "exhibited in the face of the cuttings). At one point a Fault of

* *Quart. Jour. Geol. Soc.*, vol. xxxii., page 535.

" unascertained throw crosses the line, affecting Coal-measures, " but not Permians. Hence it will be observed that the uncon- " formability between the Coal-measures and the Permian is most " pronounced."

Fig. 3.



a. Coal-measures. *b*. Permian Breccia. *c*. Permian Shale. *d*. Magnesian Limestone.

Magnesian Limestone.

Before entering into the details of the Magnesian Limestone proper, I must point out some beds, which, as far as this district is concerned, were (when I first surveyed it) seen only in two spots. These are shales that lie between the breccia and the limestone, and are exposed in the railway-cutting at Grives Wood. The shales have a thickness of about 15 feet, they are of a blue and light-brown colour, have a marly character, and are interstratified with bands of hard compact limestone full of fossils. They are not seen farther south, but on the west side of Hucknall Torkard a sharp anticlinal roll brings up a few feet of them, dipping to the east and the west at angles of between 70° and 80°. This roll may be seen in a cutting of the road, leading from Hucknall to Long Hills, and it is probable this same sharp roll brings the Coal-measures to the surface in the valley north of the road; but they are not exposed. Although these shales differ from the great mass of the limestone, they form a part of, or, as it were, a beginning to the Limestone series, and they pass up rather rapidly into the limestone. The following fossils, named by Mr. Salter, have been found in these beds:—

Schizodus (*Axinus*) *Schlotheimii*, of King (a species with strong transverse lines of ornament).

Schizodus (*Axinus*) *truncatus?* (a blunter species, common in upper and lower beds).

Pleurophorus costatus, Brown.

All these are found in Durham and the *S. Schlotheimii* is found in the Red Marls of Manchester, described by Mr. Binney.

The cuttings in the new branch lines of the Great Northern and Midland Railways have now exposed fine sections of these shales as shown in the woodcuts Figs. 2 and 3. As before stated, they are about 15 feet thick in the section given in woodcut Fig. 2, and consist of thin shaly beds interstratified with thin beds of limestone. And in the section given in woodcut, Fig. 3, they are thus described by Mr. Wilson:* " Succeeding with perfect con- " formity the Magnesian Limestone comes a series of thin-bedded

* *Quart. Jour. Geol. Soc.*, vol. xxxii., page 534.

" slate-coloured sandstones and shales. Inclusive of a breccia at " their base, they maintain along the Great Northern Railway " section a uniform thickness of 19 to 20 feet, which (as shown " at a point on the section) comprise no less than 75 different " beds ¼ of an inch to 8 inches in thickness. Several of the sand- " stones contain a large amount of imperfect plant-remains, woody " stems, and lignite permeated with iron pyrites; other bands are " covered by annelid markings; and at least one of the sandstone " beds shows casts of Schizodus."

The above description will also apply to the fine section on the Midland line.

There is no record of these shales having been found in the sinking of the New Watnall pits, but in the Hucknall Torkard Colliery sinkings there was found below the Magnesian Limestone 44 feet of limestone shale interstratified with dark stone (probably impure limestone), and one thin bed of conglomerate (4 inches) about 2 feet 10 inches from the bottom. If these beds represent the Permian shales they are here of double the thickness that they are in the railway cuttings at Kimberley.*

In the record of the sinking of the pits at the Bestwood Colliery there is no mention of any shales with limestone beds, or of any breccia. These beds may have thinned away in this direction.

At the Linby Colliery we find the following beds were passed through beneath the Magnesian Limestone:—

	feet.	inches.
1. Thin beds of Limestone and Clay - - -	3	0
2. Blue Marl - - - - - -	3	6
3. Impure Magnesian Limestone - - -	2	0
4. Alternations of Blue Bind with very hard stone -	20	0
5. Conglomeratic stone - - - -	1	8

These may very well represent the shales and thin beds of impure limestone of the Marl Slate with the Breccia at the base.

In the records of Annesley Colliery we find, below 17 feet 8 inches of limestone, the following:—

	feet.	inches.
White Marl - - - - -	—	6
Limestone-Bind - - -	6	0
Limestone with Lignite - -	1	8
Limestone Bind - - - -	4	0
Soft-Bind - - - - -	—	6
Limestone - - -	4	4
Limestone-Bind - - - -	64	5

In the absence of any breccia it is impossible now to indicate the exact line of division between the Permian beds and

* It is possible that the Permian may end with the thin bed of conglomerate and the 2′ 10″ of limestone shale, recorded as occurring below, may be Coal-measures, which would be more in harmony with what is known elsewhere. This will still leave 41′ of Permian shale.

the Coal-measures, though it might have been ascertained at the time of the sinking. The beds mentioned above appear from the description to belong to the Marl Slate Series; and, if so, the formation has greatly increased in thickness. The beds recorded as coming below are grey rock and blue-bind, and beneath them unmistakable Coal-measure strata very soon commence.

The second or Middle Permian, by far the largest and most important division, is the Magnesian Limestone. In this district lies the beginning or the most southern extremity of the Magnesian Limestone. It forms a very valuable building-stone, which extends northward into Yorkshire and Durham, and is extensively quarried both for building and for conversion into lime. The best stone and the most extensive quarries lie north of this district, and come under notice in the Memoirs accompanying the Geological Maps of those parts. Here, although the limestone has not that excellent quality which it possesses further north, still it is a very good building and paving-stone, and is extensively burnt for lime.

The thickness of the limestone in this district is not known to exceed 30 feet. In a well sunk in the Cinderhill Brickyard, and commenced in the Permian Marls, 30 feet of limestone were gone through; and although the bottom of the limestone was not actually reached, owing to the water that rose, the shales must have been close below. At the Newcastle Colliery it was found to be 27 feet thick, and the same at the up-cast pit on Hemps Hill. At the Kimberley Colliery 27 feet of limestone were also gone through, and here were found 2 feet of conglomerate at the bottom, which I have little doubt represents the Permian Breccia.

At the New Watnall Colliery the Magnesian Limestone was found to be 22 feet 8 inches thick. At the Hucknall Torkard Colliery, south of the village, it is between 18 and 20 feet, and about the same at the colliery on the east side of the village of Hucknall Torkard. At the Linby Colliery not more than 13 feet of good limestone was passed through, and at the Annesley Colliery 17 feet 8 inches. At the Bestwood Colliery as much as 30 feet is recorded, so it appears as if the limestone were thickening in an easterly direction, while the shales and breccia have thinned away.

The wells at Hucknall, I am told, are sunk to the average depth of 30 feet, and their bottoms are in the shales below the limestone. The general dip of the limestone, with a few undulations, is eastward from 2° to 5°, the surface of the ground inclining with the dip of the limestone; and this is the reason why such a small thickness as 30 feet spreads over so large an area.

The limestone is, and has been for a long time, extensively quarried for building, paving, and road-stone, and for conversion into lime. There are large quarries west of Bulwell, at Kimberley, north of Linby, at the Kirkby station, and south-east of Grives

Wood. All the large and most of the smaller quarries, which were open when this district was surveyed, are marked on the map.

The stone at the Bulwell Quarries is for the most part of a yellow colour, but in a few places the stone is coloured both brown and red. It is chiefly coarse-grained and slightly consolidated, affording a very poor soft stone; but there are a few thin beds of a harder and more compact character. The beds are thin and irregular, and they are chiefly quarried for the purpose of burning into lime, but in the lower part of the quarries there are a few feet of beds more regular in their deposition, and these are used for paving-stone. The general size of these slabs is 4 feet by 3 feet, with a thickness of from 4 to 5 inches, but there are some, though very rare, that are found to measure 6 feet by 5 feet. These slabs are used for little else than paving, but sometimes a few shallow troughs or water-cisterns are made from them. The stone is neither compact enough nor the beds thick enough to be put to the same uses as that farther northwards.

At the Kimberley Quarries the quality of the stone is the same as at Bulwell, but the slabs generally run to a larger size. At Strelley the limestone is of a reddish-brown colour and apparently very siliceous; indeed, it might well be mistaken for a sandstone.

In the extensive quarries that are worked to the north of Linby the limestone is a good crystalline rock, beginning to assume the character that distinguishes it in the more northern districts. The beds dip east from 2° to 3°. At the Grives Wood Quarries the limestone has been chiefly used for converting into lime, and here the beds dip south-east from 2° to 5°.

Good exposures of the Magnesian Limestone may now be seen in the deep cuttings of the new branch lines of the Midland and Great Northern Railways. The sections shown in the cuttings of the Great Northern Railway have been drawn and described by Mr. E. Wilson.*

Although the Magnesian Limestone is not much disturbed over this area, either lying flat or dipping at small angles, there are some very sharp anticlinals. One of these has been noticed as bringing up the lower beds of the Magnesian Limestone if not the Coal-measures, on the west side of Hucknall Torkard. This line of upheaval can be traced from Aldecar Wood, north-west of Linby, to Bulwell, a distance of 4 miles. Although so sharp that the beds near its centre dip nearly as much as 80°, its influence is not felt for any great distance from the anticlinal axis, for the beds assume their ordinary position in less than 10 yards on either side. Another sharp roll throws up a narrow ridge of limestone near Middle Mill, south-east of Hucknall, and a roll in the limestone is to be seen in a quarry near a house south of Wyburn, west of Hucknall, where the beds dipping north and south form a good arch.

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* *Quart. Jour. Geol. Soc.*, vol. xxxii., page 538.

Permian Marls.

The highest member of the Permian in this district is a series of beds of marl of a deep red colour interstratified with beds of calcareous sandstone.* Their true thickness cannot be exactly ascertained, for being overlaid unconformably by the New Red Sandstone, the apparent thickness varies considerably in different sections.

The best section of these marls is in the brickyard at the Cinderhill Colliery, where there is a thickness seen of between 25 and 30 feet, underlaid by the Magnesian Limestone and overlaid by the New Red Sandstone. The marls do not graduate either into the limestone beneath or into the overlying sandstone; indeed the sandstone appears as if deposited on an uneven surface of the marl. The marls in this pit are of a deep red colour and the sandstones interstratified with them white, red, and brown. The sandstones are calcareous and contain magnesia; they are very irregular in thickness, and a bed at one part of the brickyard is 4½ feet thick and entirely thins away in less than 50 yards. The beds in the brickyard dip to the north-east at an angle of between 4° and 5°. This deviation from the general dip of the strata of this district is accounted for by a Fault on the north side of the brickyard, striking north 60° to 65° west, and throwing down the rocks on the south side. The Fault was seen in a cutting of the Cinderhill Branch Railway, which it crosses between the two bridges. It has an inclination to the south, and was passed through in the deep-pit sinking at Cinderhill.

Since the above was written (1860) this brickyard has been extensively worked and a second Fault is now exposed to view. It strikes from the Cinderhill Railway-bridge in a direction W. 35 N. and has a down-throw to the north bringing the Mottled Sandstone against the Permian Marls, and showing that the small tongue of this sandstone is thrown down between two Faults. In the first edition of the map, the boundary between the Permian Marls and the Mottled Sandstone was drawn as a natural one, and this was a correct inference from the evidence then exposed, because the new Fault, having but a very small throw, sometimes passes within the Mottled Sandstone,—that is, brings down higher beds of sandstone against lower, and then for a few feet the boundary is seen as a natural one, the Mottled Sandstone resting on the worn surfaces of the Permian Marl, as was noticed before the sides of the brick-yard were cut back. This Fault, though of small amount, is very interesting owing to its being so favourably exposed for examination.

In sinking the up-cast pit on Hemps Hill the Permian Marls were passed through, and I give the section to show the succession of the beds :—

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* This is not the uppermost division of the Permian Series, for when these marls are traced to the north into Yorkshire they are found to pass underneath an Upper Limestone formation, which is again overlaid by other Permian Marls.

	yd.	ft.	ins.	
Red sand and gravel (Drift) - -	1	1	0	
Layer of white marl - - -	0	0	4	
Strong red sandstone (Mottled Sandstone) - - -	13	0	3	
Red marl - - -	0	1	3½	Permian Marl, 7 yards.
Strong greystone	0	0	1½	
Red marl, soft - - -	0	0	9	
Brown stone -	0	1	8	
Yellow do. -	0	0	5	
White marl -	0	0	3	
Red marl - - - -	1	0	5½	
Strong greystone -	0	0	4	
Red marl - -	0	0	6	
Strong grey sandstone - - -	0	0	4	
Red marl intermixed with sandstone -	0	2	9	
Strong grey sandstone - -	0	0	5	
Red marl - - - -	0	0	3	
Grey sandstone - -	0	0	10	
Red marl - -	2	1	8	
Yellow limestone - -	8	0	0	Magnesian Limestone, 9 yds. 1 in.
Bluish-grey limestone -	0	2	3	
Brown limestone - - -	0	0	10	
Coal Measures.				

Some of the pits of the new collieries have been sunk through these marls. In the "New Watnall" pits, 17 feet and 18 feet respectively of red and white marls were found lying above the Magnesian Limestone. In the Annesley Colliery records of the sinkings we find mentioned,—

	ft.	in.
Sand-rock - - -	31	1
Red clay - - -	2	0
Sand-rock - - - -	14	1
Red clay - - - -	13	3
Clay and sand mixed -	26	9
Limestone (Magnesian) - -	26	9

In the above section it is uncertain which beds belong exclusively to the Permian Marl series, as there are marly patches and thin irregular beds of marl in the lowermost part of the Mottled Sandstone; but I am disposed to think that the Permian commences either in or at the bottom of the first 31 feet. If this be so, there must be a greater thickness of sand-rock here than is generally met with in the Permian Marls.

The Permian Marl may be seen at Bulwell, at the Lime and Brick Works, where also pottery is made; and west of Hucknall Torkard is another brickyard in this formation, and here there is a thick bed of calcareous sandstone near the base of the marl. A section of these marls may be seen in a cutting of the Nottingham and Mansfield Railway, between Hucknall and Bulwell. Near the Kirkby Station is another brickyard in Permian Marl. The most southerly point at which these marls are known to occur is at an old brickyard west of the Two-Mile Houses, west of Basford. South of this they are overlapped by the Mottled Sandstone; but northwards they form a rather regular band, lying between the Magnesian Limestone and New Red Sandstone; and though not always seen, their position is pointed out by the moistness of the

ground and the springs that are thrown out at their junction with the sandstone,—such as the powerful spring called Bulwell Spring, north of that village, where both the Marl and Mottled Sandstone may be seen. The water of the lakes at Newstead Abbey is kept up by these marls, and is derived from strong springs, such as Mosley Spring, which is thrown out near the junction of the Permian Marl and Mottled Sandstone.

South of Annesley Park the boundaries of the Permian Marl are not very clear, there being much Drift both of sand and clay; a clay-drift over the limestone making the surface of the ground not unlike that over the marls. At Watnall the thin band of Permian Marl coloured in the map is not seen, but inferred from the springs and the red marly look of the ground. Near Kimberley there have been brickpits, and marls are to be seen at the north end of the Strelley ridge.

NEW RED SANDSTONE.

The New Red Sandstone or Trias of this district consists of various members, both of the Bunter and Keuper beds.

There is no passage from the Permian Beds upwards into the New Red Sandstone, in fact there is a considerable break between them, the New Red Sandstone overlapping various members of the Permian series, although the proofs are not all afforded in this district. In Yorkshire the New Red Sandstone rests on much higher beds of the Permian series than it does in this area. We have there an Upper Magnesian Limestone, and above that an upper series of red marls called the Upper Permian Marls, the Permian Marls of the Nottingham District being the middle marls, and lying between the Upper and Lower Magnesian Limestones. I have stated in the Explanation of 82 N.E. that the New Red Sandstone overlapped the Upper Permian Marls throughout the greater part of that district (illustrated in the Geological Survey Map 82 N.E.) and in the neighbourhood of Worksop the whole of the Upper Limestone is overlapped. From Worksop southwards to Nottingham the Middle Marls are frequently overlapped by the New Red Sandstone, and, finally, west of Nottingham the Lower Magnesian Limestone itself is overlapped, the New Red Sandstone resting on the Coal-measures. Although this break is complete, it is not to be compared to the break between the Carboniferous and the Permian, for before the latter was deposited there was a great upheaval of the older formations, followed by denudation; so that the Permian strata were deposited on the upturned edges of the Carboniferous rocks, as shown in the woodcut, Fig. 2, in the description of the Permian Breccia. There can be no doubt that there is a certain amount of conformability between the New Red Sandstone and Permian, there not having been any considerable amount of upheaval of the latter before the commencement of the deposition of the former, probably not much more than between the Middle Marls and the Lower Magnesian Limestone or between the Keuper and the Bunter; though some

amount of denudation must have taken place as the New Red Sandstone is frequently seen lying on the abraded surfaces of the Permian strata.

Bunter.

Of the three divisions of the Bunter Beds only two occur in this district; the Lower Red and Mottled Sandstone and the Pebble or Conglomerate Beds, the Upper Mottled Sandstone being absent.

Lower Red and Mottled Sandstone.

This, as the name implies, is a sandstone of a red colour, or mottled red and yellow. It is not of any great thickness in this district, and does not occupy much space. Sections of these beds may be seen on the east side of the river Leen, between Basford and Radford, in the brickyard at Cinderhill, at Bulwell Spring overlying Permian Marl; and at Middle Mill, south-east of Hucknall, where red sandstone was exposed in digging the foundation of a house. A small outlier of sandstone was cut through by the railroad south-east of Hucknall. There is a quarry in red sandstone about a quarter of a mile S.S.W. of Newstead Abbey, and north of Papplewick Hall this sandstone has been excavated into a small cave known as Robin Hood's Stable. It is also exposed along the steep escarpment of Robin Hood's Hill, capped by the Pebble Beds, and a very good section is seen on each side of the Kirkby Forest Tunnel. Here about 70 feet of sandstone are exposed, and this is probably its total thickness in this spot, as well as its greatest thickness in the district, for although nearly covered by Drift, judging from the level, the topmost bed seen must also be about the top of the formation; and the lowest bed seen must also be close above the Permian Marl, the position of which, though not exposed, is indicated by the wet ground and springs. The Red and Mottled Sandstone was again exposed in laying the foundation of a house west of Kirkby Station.

Drift Gravel covers the ground between the Kirkby Forest Tunnel and Annesley; but in several places on the east side of the ridge some soft red sandstone capped with sandstone containing pebbles is exposed. It may be seen also at Annesley Hall, and about half a mile S.S.E. of the hall there is some hard, red sandstone. South of this spot the ground is much covered with Drift gravel, but at Misk Farm there is a red sand, and south of it some red sandstone which is undoubtedly part of the Lower Red and Mottled Sandstone. At the east end of Long Hills there is some reddish-brown stratified sand, quite unconsolidated on the top, but getting slightly consolidated towards the bottom, though even there it can be broken up by the fingers. These beds do not resemble any of the Lower Soft Red and Mottled Sandstone in other parts of this district, except by being a stratified sand free from pebbles, and it has a too compact and stratified appearance for Drift. The top of the hill is certainly covered by gravel, but the sand-beds of the pit are more likely to be some local modifica-

tion of the Lower Soft Red and Mottled Sandstone. The small outlier at the Knabs is doubtful; it may be Drift-sand. At Watnall there is a small outlier of the Lower Red and Mottled Sandstone, underlaid by marl, at a spring on the east side of the hill. On Kimberley Knowl there are beds of brown sandstone overlaid by a brecciated conglomerate. This sandstone is not like the undoubted red rock, neither is the conglomerate above like the Pebble Beds, but they are in the same position as those beds, and lie on the Permian Marl. There is a thinning out of the Soft Red Sandstone in this direction, and it may undergo a change in its composition.* This outlier is bounded on the south and south-west by Faults, which throw down northward, the Magnesian Limestone on the south and west sides being on a higher level than the sandstone.

The outlier of Lower Red and Mottled Sandstone at Strelley is rather doubtful, as no section of it was exposed, only some red sand having been dug out at the south end of the ridge. The whole of the ridge is covered with Drift, which may entirely take the place of sandstone, resting on the Permian Marls, the position of which there can be no doubt of, as they are exposed in the railway cutting north of Strelley Mill, and besides may be inferred from the springs thrown out round the ridge. It seems very probable that if the Drift were cleared away the Lower Soft Red and Mottled Sandstone would be exposed below. On Catstone Hill the Lower Soft Red Sandstone is exposed in a pit on the south-east side. It is a red sand, scarcely consolidated enough to be called a sandstone, streaked with a few lines of white quartz sand; the bedding is very irregular and ridge shaped, with lines of false stratification. About 20 feet of these beds are exposed in this pit. Here there are no marls dividing the sandstone from the Magnesian Limestone.

The Hemps Hill outlier is covered with Drift-gravel, but the boundary between the marl and the sandstone is easily traceable by the springs and the contrast between the dry and wet ground. Thirty-nine feet of the sandstone was sunk through in the up-cast pit, and it is also exposed at a spring at its junction with the marl, north of Bagnall.

The Hemps Hill outlier has now† been cut through by the Derby branch of the Great Northern Railway, and a fine section of the sandstone exposed; this section has been briefly described by Mr. Wilson in his paper before noticed; he says there are about 30 feet exposed of the characteristic Lower Mottled Bunter Sandstone, including a lower brecciated portion. This breccia, he says, "is alternately sandy, marly, and calcareous," and it contains "semi-angular green, blue, and purple slates more or less rounded, "grits, quartzites, quartz-breccia, and numerous white and dis-"coloured slabs and nodular balls of fossiliferous Carboniferous "Limestone chert."

* This was written in 1860, see further remarks on page 23.
† Since the first edition of the Memoir was written.

Further on Mr. Wilson says, "Beneath the breccia comes a "series of comparatively hard red-and-yellow-mottled and soft grey "sandstones becoming, after exposure, chocolate-coloured, in beds "1 inch to 1 foot thick, obliquely bedded, and containing central "layers of purple marls, especially in their lower portions." Mr. Wilson goes on to speculate whether this sandstone is Bunter or Permian, or a passage between Permian or Bunter, but he informed me he has convinced himself that this bed is of Bunter age only. It is no doubt the same bed that was passed through in the sinking of the upcast pit on Hemps Hill given by me on page 19, recorded as strong red sandstone (Mottled Sandstone). The same bed occurs in the Cinderhill brickyard.

East of Kimberley, on the south side of the main road, is a large quarry in red sandstone, with lenticular beds of marl and also brecciated beds near the top. These may be the same beds as those in the cutting at Hemps Hill, the sandstone having precisely the same compact appearance. The beds in the quarry have a dip to the N.E., which carries them to the top of the knoll. The quarry has been opened since I first surveyed the district, but I noticed on the knoll beds of brown sandstone, overlaid by a brecciated conglomerate which I have mentioned at page 22. I there remark that the sandstone is not like the undoubted red rock (*i.e.*, Lower Bunter Sandstone), neither is the conglomerate above like the Pebble Beds, but, as they occupied the same relative position as those beds, I speculated on the thining out of the Lower Mottled as well as a change in the composition of the beds; but the cutting at Hemps Hill, and this quarry put these beds in their proper position, the lowest part of the Lower Bunter. No doubt these lenticular beds of breccia are exceptional in the Lower Bunter, and when I first surveyed the district I was not prepared to meet with anything of the kind. Lenticular beds of marl occur in the lower part of the Mottled Sandstone near Bulwell Spring.

Annesley colliery-pits were commenced in the Lower Bunter, and 30 feet of sand rock is recorded with 2 feet of red clay below; but it is not clear from the records of the sinkings where the Bunter ends and Permian begins. In the records of the sinkings of the Bestwood Coal-pits, commenced in the Pebble Beds near the junction with the Lower Mottled, we experience the same difficulty in precisely assigning the strata named to their respective formations, though it could probably have been done when the sinkings were going on. The following section is recorded as far as the commencement of the Magnesian Limestone:—

	ft.	ins.
Soft grey sand	9	3
Brown sandstone	3	6
Hard, red sandstone	1	0
Reddish-brown sandstone	22	11
Red marl	0	10
Red sandstone	3	6
Red marl	0	9
Hard, red sandstone	11	6
Free sandstone (marl partings)	3	4

	ft.	ins.
Red marl	2	9
Hard, red sandstone	3	7
Red marl	0	7
Hard, red sandstone	9	8
Red sandstone with pebbles	3	6
Red sandstone (marl partings)	1	3
Hard red sandstone	4	10
Purple sandstone	1	6
Red, sandy marl	1	2
Yellow, calcareous rock	1	1
Red, sandy marl	0	3
Red marl	4	8
Red, calcareous rock	9	5
Red marl	1	0
Yellow, Magnesian Limestone	0	0

The first 9 feet 3 inches of soft grey sand is probably drifted sand; there is no mention of any gravel or pebbles. How much, if any, of the next 4 or 5 feet may belong to the Pebble Beds it is impossible to say, but no doubt the 22 feet 11 inches of "reddish-brown" sandstone are Lower Bunter, and I am disposed to think that the whole of the hard red sandstone with the thin beds of red marl (probably lenticular beds) as far down as the purple sandstone may be also included in the Lower Bunter. This would include the red sandstone with pebbles, which may correspond to the breccia in the Hemps Hill cutting and on Kimberley knoll, and would give 76 to 78 feet for the Lower Bunter, leaving 18 feet for the Permian Marl.

The Lower Red and Mottled Sandstone of Wollaton Park rests directly on the Coal-measures, neither marl nor limestone being seen along its base. This sandstone is of the usual character, and sections of it may be seen at Wollaton, and west of Lenton, where some thickness is exposed of soft sandstone irregularly bedded, of a red colour streaked with a few lines of white.

Very lately, in excavating for the new gasometer at Radford there was found below the Alluvial gravels of the river Leen, beds of soft unconsolidated red sand with light-coloured blotches, and a breccia in the lower part. These are, probably, the basement beds of the Lower Red and Mottled Sandstone.*

Two very small outliers of the Lower Red and Mottled Sandstone have lately been opened out for their sand. One of these outliers rests on the Coal-measures in Balloon Plantation, the other on the junction of the Magnesian Limestone and the Coal-measures in Broomhill Plantation, south-east of Old Park Farm.† Both are composed of unconsolidated soft red sand with light-coloured blotches.

* The discovery of Bunter at this spot, where Coal-measures were supposed to underlie the Alluvium, will throw the greater part, if not the whole of the eastern portion of Wollaton Park, into the Bunter, otherwise the existence of a considerable north and south Fault would have to be assumed. The lower ground of Wollaton Park is covered by a clay-drift, which rendered the determination of the nature of the underlying rocks difficult.

† This small outlier was pointed out to me by Mr. C. J. A. Crawley, of the High School, Nottingham.

Pebble or Conglomerate Beds.

This formation is composed of yellow, brown, and red sandstone and sand, containing pebbles derived from various older rocks, but they are chiefly quartzites, small and rounded. In some parts the formation consists of beds of hard conglomerate, while in others it is only a loose sand with pebbles, and there are all gradations between. When the beds are unconsolidated it is often difficult to distinguish them from the overlying Drift, with which, on the surface, their loosened sand and pebbles often get intermixed. The best exhibition of the Pebble Beds in this country is at the town of Nottingham, where the harder beds form the striking and picturesque rock on which the Castle stands. It is here a yellowish sandstone full of pebbles in thick and massive beds. The rock is not so hard but that it can be easily worked, but such is its massive consolidation, and so few are the lines of bedding or joints, that it can be hollowed into large square-chambered caverns without requiring any artificial support for the roof. Advantage has been taken of this peculiar structure, and of the dryness of the rock, for along the face of the cliffs, chambers of various sizes have been hollowed, and when the front is built up with brick or stone they are used for dwellings, stables, storehouses, &c. Several small inhabited caves of this kind are to be seen at Sneinton, known as the Rock-houses, and on the south side of the park there are "The Rock Holes," excavations so ancient that their date is unknown. In this rock many cellars in the town of Nottingham are formed, which vary but very little in temperature throughout the year.

On the north and west side of Nottingham some of the unconsolidated beds may be seen, consisting of a mixture of sand and pebbles.

Considering the area that the Pebble Beds spread over in this country, there are comparatively few places where the rock is exposed. This is partly owing to the Drift that covers it, and also to the nature of the rock, which is not sought after for building or any other purposes, so that artificial sections are few, although there is quite enough exposed to show its extent and boundaries. It may be seen in a few road-cuttings north of Nottingham. The beds forming the outlier west of Basford are only seen on the west side in a road-cutting, the rest of the hill being thickly covered with Drift. These beds are composed of yellow and red imperfectly consolidated sand, with pebbles of quartz and quartz-rock, a few angular fragments of a soft sandstone like some of the rocks of the Coal-measures, and lumps of marl. The rock is in thick, irregular beds, with oblique lines of lamination.

Along the east side of the River Leen the boundary between the Lower Mottled Sandstone and Pebble Beds is much obscured by Drift, but the line of junction can be pretty accurately traced by the form of the ground. The beds of the higher formation being harder than those of the lower, they have resisted denudation in a greater degree, and form an escarpment or bank by which the line of junction can be traced northward to Newstead Abbey,

near which place, in Lodge Hill Moor, the Pebble Beds may be seen forming a rock that has been excavated for dwellings. The Pebble Beds are also visible in one or two places, capping the Lower Red and Mottled Sandstone on the south side of Robin Hood's Hills, and the east side of the ridge east of Annesley. The top of this ridge is Drift-gravel, but the Pebble Beds may be seen in the Gravel pit on the top. On the south end of the ridge the Pebble Beds are brought nearly in contact with the Permian Marls by a fault running N.W. and S.E. and having a down-throw to the N.E.

A new road* has been cut through the northern end of this outlier, a little south of Annesley church, which has exposed a section nearly 300 yards long on each side of the road and 15 feet in height, of red-coloured soft sandstone, with lenticular beds and blotches of marl containing pebbles. Where there is a section showing sandstone without these lenticular beds of marl with pebbles, the sandstone is in appearance and lithological character exactly like the ordinary Lower Soft Red and Mottled Sandstone, and, as lenticular beds of marl (though not always containing pebbles), are occasionally found throughout that formation it indicates that there cannot be any sharply defined separation between it and the Pebble Beds. This section shows a gradual passage of the lower formation into the upper.

The rock on top of Catstone Hill, formerly supposed to be Bunter†, is composed of coarse quartz-grits, of a red or yellowish-red colour, full of pebbles of red, white, and brown quartz, quartz-rock, and a few of hard, dark slaty-rock. The pebbles are of all sizes up to 3 or 4 inches in diameter. These beds have formerly been quarried, and a good part of them removed. There now remain only some large weather-worn blocks, some still *in situ*, and others lying loose, which from their unequal wear assume many fantastic shapes. The Lower Red and Mottled Sandstone is seen here in contact with these beds.

On the west side of Wollaton Park the Pebble Beds, which are here Faulted against the Coal-measures, may be seen in the lanes that cross the hill; they consist of the usual coarse, yellow, red, and brown half-consolidated sandstone, with pebbles of quartz and quartz rock.

A fine section is exposed on the side of the road leading across the hill from the Derby road to Bramcote Moor. The cutting is more than 200 yards long and above 20 feet in height at the highest point. The matrix of the rock consists of a dull red and yellow sandstone with pebbles scattered through the whole, but sometimes collected into bunches or lenticular masses. There are a few beds of sandy-marl.

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* This road has been made since I first surveyed the District.

† This rock, as well as that which caps the Himlack stone and the top of Stapleford Hill, coloured on the first edition of the Survey map as Pebble Beds, is now considered to be of Keuper age. See remarks on Keuper conglomerate, page 33.

In the earlier editions of the Survey map the outlier of Pebble Beds in Wollaton Park was omitted by Mr. Hull, who surveyed that part. These Pebble Beds may be seen in the grounds of Lenton Firs, and there is no doubt they extend over the higher part of Wollaton Park. The outlier is cut off on the south side by an east and west Fault running through Lenton House, throwing down the Upper Keuper Marls, which were sunk through in a well at Lenton House. This Fault is a continuation of the same Fault which brings the Pebble Beds against the Coal-measures farther west.

Another east and west Fault again brings in the Pebble Beds on the south side of Highfield House, and a fine cliff-section is exposed in the grounds by the side of the lake. There cannot be any doubt as to the Fault, the Upper Keuper Marls having been sunk through in a well at the house, and found to be 98 feet thick.

Pebble Beds are exposed at the bottom of the large Gravel pit on the north side of Beeston (Quarter-sheet, 71 S.E.). They were also reached in a well sunk through the gravel on the north-east side of Beeston. Sections of them may be seen at Bramcote, underlying the outlier of Waterstones. They are Faulted on the south side against the Upper Keuper Marl and probably against the Waterstones on the east side of Belle Vue. But between Belle Vue and Lenton Grange the ground is covered by gravel, which renders the subjacent geology of that part uncertain.

At Stapleford (Quarter-sheet 71 S.W.) the Pebble Beds are exposed on the south side of the village, both in a quarry and in a natural section, where the rock has been excavated for stables and cellars. Stapleford Church does not stand on Pebble Beds, as represented by the early editions of the map, but on Waterstones, probably thrown down by a Fault.

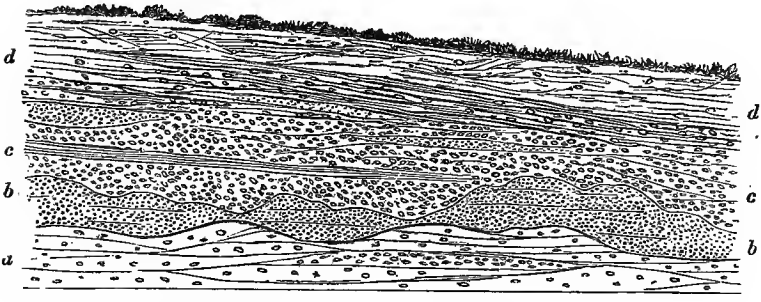
Good sections of the Pebble Beds are exposed at Sandiacre, on the south side of the church, in the road leading to the mill, and also on the north side of Cloud Hill, but they do not occur at the top of Cloud Hill (as represented on the early editions of the map) the top being entirely capped by the Waterstones.

Keuper.

In Cheshire and the adjoining counties, where the Keuper formation is very fully developed, it can, like the Bunter, be separated into three divisions. The lowest division consists of a series of breccias and coarse and fine sandstone, among the latter being the well-known Lower Keuper building stones of Cheshire. These are succeeded abruptly, there being no passage upwards, by even-bedded sandstone, often soft and porous, interstratified with beds of red marl. These pass gradually upward into the third and highest division known as the Upper Keuper Marls, a series of red marls with beds of hard white sandstone and gypsum. In the Nottingham district only the middle and upper divisions are

fully developed, namely, the Waterstones and the Upper Keuper Marls. But at the base of the Waterstones there often occurs a thin bed or beds of conglomerate resting on the eroded surface and in hollows of the Pebble Beds; below this conglomerate, and lying in hollows formed in the Bunter, has been found a coarse white sand, much like the white Keuper building-stone of Cheshire, if pounded. This sand does not occur at the surface, and has only been exposed in excavations for buildings and sewers. Even in these it might have been altogether overlooked had it not been for the diligent researches of Mr. James Shipman. The woodcut below is from one of his drawings showing the mode of occurrence of this sand.

Fig. 4.



a. Bunter Pebble Beds. *b.* White Sand (Keuper).
c. Keuper Conglomerate. *d.* Waterstones.

The following extracts are taken from an MS. description kindly given me by Mr. Shipman:—

"About a quarter of a mile west of the Westminster Abbey "Inn, and just where the spur of the Waterstones forming the "Hunger Hills dwindles into a thin veneering of greenish-grey "and red shales, capping the gentle rising ground of Bunter Pebble "Beds, excavations for buildings in January, 1878, revealed the "existence of a thin but interesting deposit of white sand lying "between the conglomerate which had hitherto been supposed to "form the base of the Keuper in this district, and the yellow "pebbly sandstone of the Bunter. This white sand was coarse, "micaceous, only slightly consolidated, and had the sharp aspect so "peculiar to Keuper sand, varying rapidly in thickness according "to the inequalities of the Bunter surface on which it was deposited. "The Bunter had evidently had time to become consolidated and "eroded into small low peaks and ridges with cavities between "of from a few inches to several feet before the deposition of the "White Sands. It should be mentioned, however, that where the "Waterstones are seen to rest directly on the Bunter, the latter "seldom presents anything like such marked signs of erosion. Small "pebbles, chiefly white and pink quartz, were met with in these "beds, but they were mostly found in 'pockets' in the cavities in "the Bunter. The White Sand here formed a sort of outlier, "apparently deposited in a shallow area eroded in the Bunter

" Pebble Beds, for it was found to be cut off on nearly all sides, the " 'Waterstones' resting directly on the Bunter. Where the White " Sand was more consolidated there were very clear indications of " erosion before the formation of the three or four feet of rusty- " coloured lenticular beds of shingle and red and greenish marl that " rest upon it, and fill up cavities in its upper surface."

"Not long (three months) afterwards a much greater develop- " ment of similar white sandstone, now, however, associated with " conglomerates and seams of red clay, was discovered by Mr. E. " Wilson, F.G.S., at Rough Hill Wood, at the south end of the " town during the progress of excavations for the Leen Valley out- " fall sewer under the foot of this escarpment. The base was not " seen here, although a thickness of about 18 feet of these beds was " passed through. The following was the section as measured by " Mr. Wilson:—

	ft.	ins.
Waterstones { Thin-bedded, greenish-yellow sandstone and marl, with sun-cracks and ripple-marks, with string of pebbles at base -	3	6
Yellow sandstone with strings of small pebbles -	0	4
Coarse white sandstone becoming coarser below, with scattered pebbles, and a seam of red marl; current-bedded - - - - - -	6	0
Coarse, light-grey sandstone, obliquely bedded - -	2	0
Red and green marl, lenticular band - - -	0	3
Fine-grained, dark greenish-grey, micaceous sandstone, with a few pebbles, and a thin seam of clay - -	1	9
Yellowish-red sandstone, with odd pebbles - -	0	7
Red and green marl - - - - -	1	7
Greenish-grey fine sandstone - - - -	0	8
Red and green marl - - - - -	0	7
Coarse greenish-grey sandstone, with flakes of green clay	0	7
Red and green marl - - - -	0	6
Light, greenish-grey grit, with pebbles and green clay flakes - - - - - - -	0	7
Red and green marl - - - - -	0	6
Light greenish-grey grit (base not proved) -	3	0
	21	4

" The sandstone consists of clear sharp colourless quartz grains, " with much decomposed felspar and a good deal of mica. It has " a bluish-grey tint, except where locally stained. The oblique " bedding falls east at high angles. The pebbles are mainly " quartzites, quartz, with occasional fragments of green slate, Car- " boniferous chert, and dolomitic limestone. In general character " the pebbles agree with those of the Bunter Pebble Beds, but " differ in having one or more angular faces, as if fractured during " the process of deposition."

Whether this white sand is a thin representative of the Lower Keuper Building-stones, and the conglomerate above it of the Breccias of the Lower Keuper, is at present uncertain; but when the line dividing the Lower Keuper from the Middle Keuper or Waterstones is traced, as is now being done in Cheshire, over the whole of the country intervening between Chester and Nottingham, it may be possible to arrive at some definite conclusions.

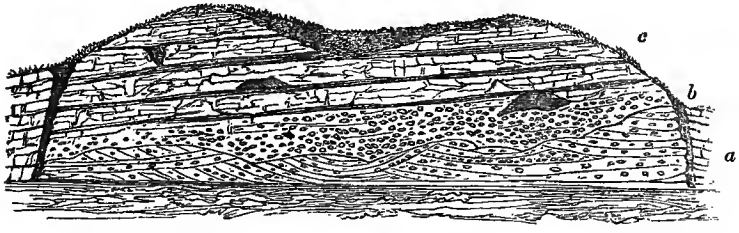
Keuper Conglomerate.

There are several localities on the east side of Nottingham where the conglomerate may be seen, at the junction of the Bunter and Keuper, lying on eroded surfaces of the lower formation, the break between the Bunter and Keuper being complete.

To Mr. Shipman the credit is entirely due for assigning the place of this conglomerate to its right position at the base of the Waterstones. In a communication to the "Geological Magazine" he says: "Recent excavations for buildings on the east side of "Nottingham have afforded opportunities for observing the true "character and development of the conglomerate at the base of "the Lower Keuper (*i.e.*, Waterstones), which did not exist when "this district was visited by the Government Geological Survey," (now more than 20 years ago). Farther on in his communication Mr. Shipman says: "It was not until two or three years ago that, "discovering the calcareous nature of what had been always "regarded as the top of the Bunter, I was led to examine the "junctions at other spots. Since then the further opening up of "the ground along the line where the Keuper begins to overlap "the Bunter, has enabled me to collect tolerably complete data "as to the development of the conglomerate in this neighbourhood. "It may be here mentioned that chemical analysis has shown that "the matrix contains a very large proportion of magnesia as well "as lime. Generally the conglomerate is found to occupy the "slightly angular, or rounded, shallow cavities of an eroded surface "of Bunter, and as the Keuper reposes somewhat obliquely on "the Bunter there is an unmistakeable unconformity. The con-"glomerate is thickest at its outcrop, and as it passes beneath the "Keuper seems to lose some of its compactness, and in one spot "I have seen, is represented by pebbles stuck in a deep red "marly sand. Its usual development, however, is in the form of "a ferruginous compact crystalline band, thickly studded with "pebbles, and so hard that it is dreaded even by navvies; it "varies in thickness between six inches and two feet, and is some-"times swollen by lenticular beds of coarse bleached sandstone "as much as three feet thick." Mr. Shipman goes on to say: "The most interesting exposure of it about Nottingham existed, "until lately, on the Hunger Hill Road, and its character at this "spot may be taken as fairly typical of its fullest development. "The conglomerate itself consists of pebbles, chiefly of quartz "and quartz rock, with fragments of trap, volcanic ash, clay-stone, "greenstone, slate, chert, bits of yellowish Permian Magnesian "Limestone, and other rocks, with a good deal of calcareous "matter coating some of the pebbles, in a ground-up form, and in "minute crystals. Resting on the conglomerate was a thin bed "of grit cemented into cakes by calcareous matter, then about "two feet of bluish-grey soft bleached sand, irregularly bedded, "but having a general slope of about 5°, and passing under the "Keuper." (*i.e.*, Waterstones). Mr. Shipman gives a sketch of

another good section in Turner Street, showing the manner in which the conglomerate rests on the Bunter.

Fig. 5.



a. Bunter Pebble Beds. *b.* Keuper Conglomerate. *c.* Waterstones.

The conglomerate in this section is surmounted by thick and thin beds of brown sandstone, with marl partings. Another section shows the conglomerate, which I had in my first survey considered to be Bunter, to the east of the main road south of Red Hill. I described those as thick beds of very coarse half-consolidated sandstone of a yellowish and reddish-brown colour, containing pebbles of quartz, overlain by beds of red sandy marl with beds of fine-grained yellow sandstone. This is a true description of the section, but at that time I considered the lower beds as Bunter, and the higher as Keuper. There were a few small pebbles in the lower part of the upper series, but there was a very apparent difference between the two sets of beds. Mr. Shipman, in writing of this section says: "When I first visited this spot, I too regarded the "'thick beds' (about four feet thick) as Bunter, but on a second "visit, after a long and careful study of the Keuper conglomerate "at Nottingham, my suspicions were aroused by the striking "resemblance between the thick beds studded with quartz-pebbles, "and precisely the same deep-red half-consolidated sandstone "associated with the Keuper conglomerate, and a removal of the "vegetation shrouding the lower part of the section, revealed a "compact ferruginous conglomerate, eight inches thick, below the "massive bed of sandstone, and separated from the Bunter—a "coarse yellow sandstone containing scarcely any pebbles—by "about 12 inches of soft red marl."

The best section seen when I first visited Nottingham, showing the junction between the Bunter and the Keuper, was in a lane leading from the Mansfield Road, a mile north of the town (at that time), to the Mapperley Hills. Near the bottom of the lane there are beds of coarse sandstone slightly consolidated, containing pebbles of variously coloured quartz, quartz-rock, and other sandstone. There is no good bedding visible in this conglomerate, and lying on it there are thin and regularly bedded fine sandstones of a brown colour. Here there is no doubt that the lower part of the section consists of the Pebble Beds of the Bunter. But Mr. Shipman has noticed here a thin bed which he considers Keuper conglomerate lying on and encrusting the slightly eroded surface of the Bunter.

The following are the details of two measured sections at the junction of the Keuper and the Bunter, by Mr. Shipman:—

SECTION No. 1, IN TURNER STREET.

	ft.	ins.
Red marl with thin streaks of light-green clay	2	0
Fine argillaceous light-green sandstone; slightly laminated and rippled	3	9
Light-green clay with streaks of red and yellowish sandstone	1	9
Red and buff sand, sometimes marly and purplish, dolomitic, with scattered pebbles of quartz, quartzite, chert	1	0
Light-grey coarse sand, mottled and containing a few pebbles	1	6
Conglomerate forming base of Waterstones	2	0
Bunter Pebble Beds.		

SECTION No. 2.—Half a mile to the north-east of No. 1 section, close by Westminster Abbey Inn, where three distinct bands of conglomerate were met with towards the base of the Waterstones.

	ft.	ins.
Greenish laminated sandstone	4	0
Laminated red and greenish marlstone with occasional quartz pebbles	1	0
Red clay	0	2
Greenish-yellow sandstone, laminated, with a few quartz pebbles	1	4
Light-green sandstone, with streaks of red marl, and quartz pebbles in lower part	1	7
Quartzose conglomerate. Matrix, coarse red sand containing pebbles up to 1½-inch long, thickness variable. Details were—		
Light-grey and white grit — 4 ins.		
Yellowish grit with pebbles — 8 „	1	10
Dull-red sand and pebbles — 6 „		
Greenish-grey sand and quartzite pebbles 4 „		
Greenish-yellow soft sandstone with strings of quartzite pebbles	1	6
Quartzose conglomerate in a reddish and greenish-yellow sandy matrix, partly cemented	1	0
Thin seams of red and light-green marl and red sand	0	4
Greenish-white fine sand, and quartz pebbles	0	5
Coarse red sand containing small pebbles	0	8
Quartzose conglomerate containing large and small pebbles firmly cemented in a rusty-coloured base, resting on yellow Bunter Sandstone	0	6
	15	2

Bramcote Hill, east of the Himlack Stone, is capped with a hard pebbly reddish calcareous conglomerate, precisely of the same character as that at the base of the Waterstones and unlike the ordinary conglomerate of the Middle Bunter on which it rests. The conglomerate at this spot must be at least 30 feet or more in thickness, which makes it of some importance, and might lead one to consider it to be equivalent to some of the conglomerate beds in the Lower Keuper farther westward.

Similar conglomerate to that on the top of Bramcote Hill also caps the Himlack Stone, Stapleford Hill, and Catstone Hill. These outliers have hitherto been considered as belonging to the Pebble Beds of the Bunter,* but on visiting them again lately I was strongly impressed by their resemblance in general character to the conglomerate that is found at the base of the Waterstones at Nottingham and elsewhere in the district, and I now therefore regard them as Keuper, and not as Bunter.

On Bramcote Hill the hard conglomerate rests on the ordinary Pebble Beds of the Middle Bunter, but the conglomerates that cap the Himlack Stone, Stapleford Hill, and Catstone Hill, repose immediately on the soft Lower Mottled Sandstone of the Bunter. Therefore, if my supposition be correct that these conglomerates are Keuper, it shows a rapid overlap of that formation.

Hard pebbly conglomerate underlies the Waterstones at the village of Bramcote (Quarter-sheet, 71 S.E.), and at Sandiacre (Quarter-sheet, 71 S.W.) is exposed at the north-east corner of the churchyard. In both these localities there can be little doubt as to the formation of which they form a part; there, as at Nottingham, they constitute the base of the Waterstones, lying on the ordinary Pebble Beds of the Bunter. They are Keuper, and, on comparing hand specimens, I could not detect any difference between these conglomerates and those of the Himlack Stone, Stapleford Hill, and Catstone Hill.

Blocks of Keuper Conglomerate occur on the south-east side of the Bunter Pebble Bed cliff in Highfield House grounds, but here the section is not clear enough to enable one to say with certainty whether they are *in situ*, or whether they have slipped from a higher level.

It is highly probable there are many other localities at the base of the Waterstones where this Keuper conglomerate occurs, but of which at present we have no exposures.

Waterstones.

The Waterstones or Middle Keuper consist in this district of brown and whitey-brown soft sandstones and red marls. These are extensively worked for brick-making, both sandstones and marls being ground up together. There are many sections of these beds in the district, most of the brickyards on the east side of Nottingham being in them, besides many road and brook sections; but perhaps some of the best sections may be seen in the cuttings on the north side of the Nottingham and Lincoln Railway, north of Colwick.

Owing to the porous nature of the sandstones, they contain a a large quantity of water (hence the term Waterstones), which is in places thrown out in copious springs by the marly beds at or near their base.

In the northern part of this district there are some alternations of soft blue sandstone and blue clays at the base of the Water-

* See page 26.

stones. They are nowhere well exposed, except at the brick-kilns east of Farnsfield, and there is not there any very good section, but they assume a greater importance in the country farther north, and are noticed in the Memoirs on that district.

There are two small outliers of the Waterstones resting on the Pebble Beds in Beeston Field, on the south-west side of Wollaton Park. These escaped the notice of Mr. Hull when he surveyed that part, but they are now laid down on the newly-revised map. Waterstones may be also seen on the Derby road, by Lenton Abbey, but whether they lie here naturally on the Pebble Beds or are Faulted against them, the exposures are not sufficiently good to show. There is, however, no doubt that this part is much disturbed, and there may be more than the one Fault shown on the map.

In the district to the south (Quarter-sheet, 71 S.E.) lying north-west of the Trent there is an outlier of Waterstones at Bramcote Faulted on the S.W. side against the Upper Keuper Marls; the beds are well exposed and are of the usual character. The conglomerate at the base has already been referred to. There is another outlier at Belle-vue, where the beds are not well enough exposed to get its outline very accurately, but there are loose fragments of the rock in the ditches and banks, and the red colour and moisture of the soil contrasting with the light sandy soil of the Pebble Beds, indicates its position. A Fault must bound the east side of this outlier, with a down-throw on the west, or, judging by the surface configuration of the ground, it would have extended further eastward.

The ground between Belle-vue and Lenton Grove, coloured on the map as Waterstones, is very obscure. There being no spot where the rock is exposed, nearly the whole of the ground being occupied by large nursery gardens in which the soil is found to be red and stiff, it is quite impossible to trace, with accuracy, the boundaries of this supposed outlier of Waterstones,* neither is it possible to ascertain whether they are natural or Faulted. I believe the south and west sides may be Faulted by a continuation of the Highfield House Fault. The north boundary is quite uncertain, as the heavy soil extends to the road at Beeston Field, but, I believe, this may be caused by a clay-drift covering over the low ground south of that locality.

Stapleford Church (Quarter-sheet, 71 S.W.) stands on the Waterstones, though in the first edition of the survey map this part was coloured as Pebble Beds; but the graves in the churchyard are dug in the soft sandstones and marl of the Waterstones, and good sections of the same may now be seen in more than one place on the east side of the road that runs by the church; I believe the Waterstones must be thrown down to this low level by a Fault, the direction of which can be pretty well ascertained, for in a drain made along the cross-road running south-east from

* It is quite possible that the stiffness and redness of the soil may be caused by a deep drift of red clay.

a little north of the church to the main street, Pebble Beds appear to have been met with.

It has been stated in writing of the Pebble Beds that the boundary between them and the Waterstones on Cloud Hill, Sandiacre, (Quarter-sheet, 71 S.W.) was incorrectly mapped in the first edition of the Survey map. The boundary does not strike directly north from the road which runs west from the village, but follows the contour of the ground, bends to the east, and strikes the north-west corner of Sandiacre Churchyard, where, as before stated, the Keuper Conglomerate may be seen resting on the Bunter Pebble Beds. The whole of the top of Cloud Hill therefore consists of Waterstones, a fact which is also corroborated by the colour and nature of the soil, and the fragments of the rock found in the ditches and banks. It is not quite clear whether the boundary on the north side of the hill may not be a Fault. If the Pebble Beds that crop out on the side of the hill lie horizontally, it is probably a Fault. On the other hand, if they have a dip of any amount to the south it may be a natural boundary. It is not possible to ascertain the dip in these beds from a small exposure.

Upper Keuper Marl.

The Waterstones pass gradually into the Upper Keuper Marls, there being no marked line between them, and it is often puzzling to decide where to draw the boundary. The thick-bedded soft sandstones and marls gradually pass upwards into thinner beds of a harder sandstone, interstratified with thicker beds of marl. There are many sections showing this gradual change, in the road-cuttings and clay-pits east of Nottingham, but in one or two of the road sections the strata are brought together by Faults, and at these spots the difference between the two can be best studied. As the Faults are marked on the Map, there can be no difficulty in finding the spots.*

The Upper Keuper Marls are often variegated with blue or white streaks, with numerous interstratifications of thin beds of hard white sandstone, and in some places gypsum occurs. Near Nottingham there are many large brickworks in this formation, the chief of which are situated on the ridge north-east of Mapperly House, and on the road from Nottingham to Carlton. In all of these the white sandstone may also be seen. There are many other smaller brickworks scattered over this formation.

Sections of the Waterstones and Upper Keuper Marls occur around Carlton and Gedling. In the deep gully called Lambley Dumble and Lambley Dale the junction beds may be seen, where, the dip being at the same angle as the inclination of the ground, the same strata occupy the bed of the brook from end to end of the valley. They are composed of soft red sandstone, red marls, and greenish-white soft sandstone, sometimes ripple-marked. Although these

* Many of these spots will soon be covered with buildings (note in 1st Edition, 1861). This is now the case, but Mr. Shipman having sketched some of these faulted junctions when exposed to view, a lasting record of them is preserved (1880).

beds as a whole dip at a gentle angle, there are one or two spots where they have been squeezed into sharp arches or anticlinals as if they had been subjected to lateral pressure, but these sudden disturbances in the strata are not appreciable for more than a yard or so on either side of the axis. The same thing may be seen on the road from Southwell to Halloughton in red and light-coloured marl and thin beds of whitish red soft sandstone, probably the passage into the Upper Keuper Marl. There is also another anticlinal fold in Westhorpe Dumble. On the road from Southwell to Halam, the passage-beds are exposed in a cutting. In descending the hill there is first a thick bed of hard white sandstone, below which there are red marls interstratified with thinner and softer beds of white sandstone and some white clay, underlaid by the soft reddish-brown sandstones of the Waterstones. The thin blue lines, traced on the map among the marls, show the position of some of the thickest beds of the white sandstone in that formation, or of several thin ones close together; but as these beds thin away and others thicken, or new ones come in, only an approximate representation of their courses can be given. Sometimes several thin beds coalesce and form a considerable thickness of stone in a certain spot, and within half a mile disappear or become separated by beds of marl. But over the whole formation there is not 20 feet of marl without one or two beds of this sandstone either thick or thin, although the chief beds are generally found towards the bottom of the marly series. Separate beds of this sandstone are seldom thick, but there are places where they are thick enough to form good building-stones. One of these beds, a foot thick, and rather hard, occurs on the east side of Halloughton. To the north-east of Thurgarton the sandstones appear to be very plentiful, the loose fragments being scattered thickly over the slope on the south side of the brook between Rudsey Farm and Morton Field, also on the south side of the same ridge by Brick-yard Farm; and all through the country occupied by the marls, the sandstones are found strewn over every ploughed field and along the slopes of the hills.

An outlier of Upper Keuper Marls has been referred to in the account of the Pebble Beds, as being let down between two Faults near Highfield House, at which place in sinking a well they were found to be 98 feet thick. The southern boundary Fault to this outlier passes on the south-east side of Highfield House, and the northern boundary Fault, which is a continuation of the large Fault that throws down the Pebble Beds against the Coal-measures, passes close to the north of Lenton House. Mr. Hull had drawn this Fault a little way to the south of Lenton House, placing the house itself on the Lower Mottled Sandstone, but a well was sunk at this house to a depth of 114 feet, through the Upper Keuper Marls down to the Waterstones; and it is now known that the Keuper Marls are Faulted against Pebble Beds at the surface and not against the Lower Mottled Sandstone. This is now corrected on the revised edition of the map. The two Faults that throw down the Keuper formation must

meet somewhere to the west of Highfield House, probably in the vicinity of Barn Houses, cutting off the outlier of Keuper rocks in that direction, and partly neutralising each other. The western boundary of the marl is very uncertain, no sections of rock being exposed; it may, as it is drawn, rest naturally on the Waterstones.

The Upper Keuper Marls of Chilwell (Quarter-sheet, 71 S E.) are thrown down by a rather considerable Fault running from Stapleford (71 S.W.) to Beeston. This Fault was laid down in in the first editions of the maps, but south of Bramcote Grove and Belle-vue was drawn too far south. Upper Keuper marls and sandstone have been found north of that line, and the line now marked on the map is nearer its true direction. For about a mile east of Bramcote Grange the line is easily traceable by the colour and character of the soil, that over the Pebble Beds being light and sandy, while that over the Marls is red and heavy; but near Beeston the line of Fault is very uncertain, the ground being thickly covered with gravel. I have reason to believe, however, that it does not continue in the same direction, but may be affected by the Belle-vue Fault which, having a down-throw westward, may shift it farther to the south, but of this there is no positive proof. I am inclined to think that below the gravel, on which the greater part of Beeston stands, Pebble Beds will be found, but till the gravel under the village is penetrated, the geology of this small area must be considered uncertain.*

The Upper Keuper Marls are opened out for brickmaking on the west and north-west sides of Chilwell, where very good sections are exposed showing the usual red marls with several beds of the Upper Keuper Sandstone. Mr. Hull has here coloured in a large area as sandstone, but this would give a false impression suggesting that it is one massive bed, which is not the case; nor is there one bed dipping with the slope of the hill, the dips showing that direction are wholly untrustworthy. In the brickyards at Chilwell the beds are gently undulating, and clearly show that the area coloured simply as sandstone is occupied by thick beds of marl, alternating with sandstone. There is probably not more sandstone in this area than in any other part of the Upper Keuper Marls.†

Gypsum is found both in the Waterstones and in the Upper Keuper Marls, but chiefly in the lower part of the latter. It occurs in sheets between beds of marl, and ramifies about in threads, filling the cracks in and surrounding concretionary masses of marl. It may be seen at Sneinton Elements, on the east side of Nottingham, and in the cuttings of the railroad between Sneinton and Carlton; but the best exhibition of it, and where the largest quantity occurs, is on the south-east side of the Trent, at a place known as the Alabaster Pits.

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* Pebble Beds have been found below the gravel in a pit on the north side and in a well on the north-east side of the village. *See* page 27.

† This is now corrected on the revised map, pub. 1879.

DRIFT.

The whole of this country has more or less a covering of Drift, either gravel, sand, or clay, not spread uniformly, but in patches on the tops of the hills, and over the low ground; seldom on the steep sides of the hills. It lies chiefly over the northern and western part of country, in the valley of the Trent, and over part of the country to the south-east of the Trent valley, but the ground between Nottingham and Southwell is comparatively free from it. It is only at one or two places that the Drift is so thick or widely spread as to prevent our arriving at a knowledge of the underlying strata. Here and there it may obscure a boundary line for the length of a mile, but it never makes any considerable feature. When the Drift is only thinly spread over the surface it does not much modify the nature of the soil, which generally changes with the underlying strata, except when the Drift is of clay, which makes a wet soil. Over the limestone there is a light dry soil, the marls being wet, and over the sandstones and Pebble Beds the soil is sandy; yet in all these places the ground is covered with Drift pebbles, which are, however, mixed up with the underlying strata in such proportions as not materially to affect the soil formed by the decomposition of the bed below. Of course this is not the case where the thick patches of gravel occur on the tops of some of the hills. When the gravel or sand of the Drift lies over the unconsolidated Pebble Beds it is very difficult to distinguish them, and in many cases they must have become mixed.

The following are the places where the Drift is most important, either in thickness or from other reasons, and where its composition may also be best observed.

To the west of Bulwell the red Permian marl has drifted to some extent over the Magnesian Limestone, which makes it rather difficult to determine the exact relative position between the limestone and the marls in place; and this Drift has been mistaken for them. But on examination it is found to be a stiff red clay, without any sign of stratification, and contains pebbles. It is spread very irregularly over the limestone, and is so thin in places that the limestone is exposed below it in many of the ditches. There is a pit in this Clay-drift on the south side of the new branch line of the Midland Railway, and the upper part of the clay in the Bulwell clay-pits consists of this Drift-clay, evidently derived from the marls on which it rests.

The high ground extending from Robin Hood's Hills, southward over Annesley Park, is very thickly covered with Drift, and it is well exhibited in the gravel pit on the top of the ridge east of Annesley. In this pit may be seen a thick mass, composed of angular blocks of all sizes, from a foot in diameter downwards, and some angular and rounded pebbles. These are in some parts of the pit cemented together into a breccia, and in one place there is a large mass of the Pebble Beds (the underlying rock) surrounded by the gravel, while in another place there is soft Drift sand, with

pebbles. In examining the composition of this gravel, the fragments and pebbles are found to be derived from a great variety of rocks, consisting of pebbles of quartz and quartz-rock, boulders, fragments and pebbles of hard and soft sandstone, limestone, ironstone, and trap rocks. The quartz pebbles, mostly small and of various colours, were probably chiefly derived from the Pebble Beds. The sandstones are some of them red, like Old Red Sandstone (?), and others were derived from the Millstone Grit, Coal Measures, Permian, Bunter Sandstone, Upper and Lower Keuper Sandstone, &c. The limestones are Carboniferous and Magnesian. The Trap fragments are of a dark and light-green colour, compact and cellular. Some of the fragments are flat and angular, and these are chiefly of soft sandstone from the Coal-Measures. These boulders, fragments, and pebbles are mixed with coarse sand.

On the hill between Kirkby Woodhouse and Grives Wood there was a large gravel-pit, now filled up, showing some thickness of a fine stratified yellow sand, with layers of pebbles of all shapes and sizes; over this is a coarser gravel.

The Gravel Pits on the Long Hills are in Drift.

Over the Kirkby Forest Tunnel some thickness of Drift may be seen.

On the road leading from Kirkby Forest to Sherwood Place there is a large boulder of dark trap rock, measuring $4\frac{1}{2}$ feet $\times$ 2 $\times$ 3.

Near Blidworth there are large masses of cemented Drift Gravel, like that found in the Annesley gravel-pit; but instead of being in a pit they stand up in isolated masses. They are very remarkable, and are popularly known as *Druidical Remains*. These curious blocks were no doubt first roughly shaped out by the uncemented gravel having been denuded from around the cemented portions, leaving the latter standing high above the level of the ground, while some of them were afterwards shaped by men into their present forms. One of the blocks is 13 feet in height and 54 feet in circumference at the base; it is oblong, and has been hollowed out so as to form a sort of cave or hut. There are rough lines of stratification through the mass.

Another of these solid blocks has been shaped into an overhanging mass, and is about 10 feet high, 15 feet in length, and 15 feet in breadth, at its widest part.

On the west side of Basford there is a considerable accumulation of Drift, which is largely used for gravel. It also covers the red sandstone on Hemps Hill, and the ridge east of Strelley.

The village of Beeston (Quarter-sheet, 71 S.E.) stands on a thick deposit of gravel, which has been opened out in several places to some depth. In a large open pit on the north side of the village a depth of gravel from 12 feet to 15 feet is exposed, at the bottom of which are seen the Pebble Beds of the Bunter. In this gravel many chalk-flints occur.

It has been before stated that the Beeston gravel conceals the solid formations below, so that it is not possible to ascertain with

any certainty the exact lines of separation between the Bunter and Keuper formations.

I think there can be little doubt that the clay and gravel drifts that are found in the Nottingham district are marine, and chiefly derived from local sources, more especially the gravels from the denudation of the Bunter Pebble Beds. But mixed with the local drift there are boulders and pebbles that have been transported from a distance, such as the large boulder of dark trap rock and the chalk-flints. These may have been brought on floating ice; but whether the foreign pebbles in the locally derived gravels were deposited directly from icebergs at the spots where they are now found is an open question. I am now inclined to think they are derived from the denudation and destruction of an older drift.*

Alluvium.

Gravels of the Trent.

The gravel in the valley of the Trent differs from the ordinary Drift of the country, inasmuch as if it has not actually been brought down by the river, it has certainly been re-arranged by it, and spread out in a nearly horizontal position. For this reason it has been coloured like the alluvium, from which it would have been difficult to separate it on the map.† This gravel may be seen at some pits at Carlton Field House, and the pebbles composing it are derived from a great variety of rocks, quartz pebbles of all colours, quartz-rock, black chert, Carboniferous Limestone containing corals, encrinites, and fragments of shells, a dark trap rock, granite, a few flints, jasper, &c. The pebbles are generally small, some of the larger fragments being of sandstone, derived from the Waterstones, and the whole is mixed with a reddish sand, and has a slightly stratified appearance. Being mostly grass-land this deposit is not often seen, and the ground it covers is not a complete flat, though it appears so from the surrounding hills. There are a few slight undulations. The marsh-lands are formed by the fine alluvial silt and mud of the river. Some of the valley is covered by a peaty soil, in which bog iron-ore has been found near Bleasby.

River Leen.

There is only a small deposit of Alluvium in the valley of the Leen, either of gravel or loam. The breadth of the alluvial flat on either one side of the river or the other, seldom on both, is so narrow as to be scarcely discernible as delineated on the one-inch map. Where the Alluvium has been dug into near Radford, rather coarse gravel has been found, more like the drift deposits of the neighbourhood than anything that would be deposited by a small stream, and it is probable that much of the river flat is the surface drift re-arranged.

* When this district is re-mapped on a scale of six-inches to the mile special attention will be given to the superficial deposits and their boundaries traced in, and then, no doubt, some knowledge as to the origin of these Drift sands, gravels, and clays may be arrived at.

† This probably may be done on the six-inch maps.

Tottle Brook.

The Tottle Brook, though but a small stream, has deposited some thickness of Alluvium, though it does not occupy any width on either side of the stream, and it is generally too narrow to be indicated on the one-inch map without exaggerating its breadth. The Alluvium consists chiefly of tough blue or yellow clay, evidently derived from the Coal-measures, in which formation the Tottle Brook rises and over which it flows for a little more than a mile and a half. This clay is generally very free from pebbles, but between it and the Coal-measures, whenever the brook has cut deep enough, a bed of gravel varying from a few inches to a foot in thickness is seen. An exposure showing this occurs south-west of Hay Barn, on the west side of Wollaton Park, where the bed of the stream is occupied by Coal-measure Sandstone, above which on the side is a gravel bed one foot in thickness, and on this gravel about two feet of clay. The same occurence may be seen again about a quarter of a mile lower down, but here only a few inches in thickness of gravel lies between the Coal-measures (which are much broken and mixed with clay) and the stiff Alluvial clay. Between these two places, at a spot where another stream joins on the west side, the clay is much thicker, with apparently a lenticular bed of gravel in it. This may be caused by the junction of the streams, but the section is not so clear as we could wish. Below where the canal crosses the Tottle Brook there are from 3 to 4 feet of this Alluvial clay, between which and apparently broken-up Coal-measure shale there is a gravel bed only a few inches in thickness. The Alluvium here forms a narrow strip of flat ground on each side of the stream. Where the Tottle Brook cuts through the Bunter and Keuper rocks the Alluvial clay entirely occupies the bed of the stream, concealing the underlying strata; and this continues to be the case to where it joins the Alluvium of the Trent. Here the clays are well exhibited on the sides of the brook; they are dark blue and very tenacious, containing in places black carbonaceous matter, as might be expected, since they have been derived from the Coal-measures. Over the extensive flat that forms the valley of the Trent,* there is a considerable spread of this Alluvial clay, but wherever it has been penetrated it has always been found to be underlaid by gravel or sand, and is generally not more than from 3 to 4 or 5 feet thick, although there may be places where it may exceed this, as for instance, where the Tottle Brook enters, the detritus brought down by that stream may have formed a deeper deposit where it joined the waters of the Trent.

Bingham Moors.

A rather extensive Alluvial flat, known as Bingham Moors, lies on the south-east side of the district, and extends into the adjoining district.† This Alluvium consists of a stiff dark clay of unknown thickness. As there is no river flowing through the flat, but only a small brook which would be unable to deposit such an extensive

* That part of the Trent valley delineated on Geological Map Quarter-sheet 71 S.E., is here alluded to.

† See Geological Map, Sheet 70.

spread of Alluvium, it is probable that this flat is the site of a former lake or mere so frequently occurring on the Keuper Marls. The exact outline of this mere is not now easy to trace, for the slope of the ground rising from the flat is so gentle, and the dark clay of the alluvium merges so gradually into the red clay of the Keuper. This is especially the case on the north-west side. The small hill on which the farm called the Holmes stands was an island rising out of the mere.

Faults.

The chief Faults of the district have been noticed in describing the various strata, but it may be well again to refer to them and give a short notice of each.

They may be classed under two heads; those that are only known in the underground workings of the collieries, and are coloured yellow on the map, and those that affect the rocks at the surface, and are coloured white.

One of the largest known Faults that comes under the first head, and also partly under the second, was met with in the workings of the Cinderhill Colliery. It is a Fault with a downthrow to the south of 80 yards. It was passed through in sinking the deep shaft at that colliery between the "Top Hard" and "Main Soft" coals. The course of this Fault is marked on the map, running from Lower Hempshill in a westerly direction, below Nuthall Temple. There is no doubt that this is a pre-Permian Fault, but a subsequent movement has taken place along the same line which has affected the Permian and New Red Sandstone to the extent of 14 yards or thereabouts. This is the Fault that occurs in the Cinderhill brickyard, and is shown on the map by the white line running from Lower Hempshill to the north of Basford. A small Fault, with a downthrow of five yards to the west, strikes from the large Fault from near Upper Hempshill in a N.N.W. direction. This Fault is also known from the Colliery workings, but may be also the same as is seen affecting the New Red Sandstone, in the cutting of the railway. Two other underground Faults known in the Cinderhill and Newcastle Colliery workings are marked on the map, one running N.W. and S.E. under the Two-mile Houses, and the other running first in a N.W. and S.E. direction under Broxtowe Hall, then bending to the east for a short distance and finally taking a S.S.E. direction, passing on the west side of the Newcastle Colliery. Both these Faults, I am told by the Manager of the Cinderhill and Newcastle Collieries, have a downthrow to the N.E. of about 28 yards, and are apparently pre-Permian Faults. The Fault marked on the map as running W.S.W. and E.N.E. north of the Two-mile Houses, has a downthrow to the south, affecting the Permian and New Red Sandstone.

I have been informed lately that the line marked on the map as a Fault running in an E. and W. direction is not a true one, that is, the rocks are not shifted, but it was found that coal had been washed out along that line.

The Coal-measures in the Hucknall Torkard district are very

free from Faults, but in the workings of the Annesley Colliery many have been met with, chiefly throws of from 1 to 20 yards. The downthrow of the Faults running east and west is to the south, and those running north and south is to the west.

The Fault marked west of Linby is a downthrow to the N.E., and is inferred by the relative position of the beds. Some of the Faults at Kimberley are seen in the railway cuttings, the others are inferred. Little is known now of the Fault marked on the map running north and south from near Strelly to Bramcote Moor; it was marked down for me by a colliery manager when I first surveyed the country.

One of the largest post-Triassic Faults of the district is that running east and west from Bramcote Moor through Lenton House. It has a downthrow to the south, bringing in succession first the Lower Mottled Sandstone and Pebble Beds against the Coal-measures, and then passing through the Triassic rocks and throwing down the Waterstones and Keuper Marls against the Pebble Beds. It has been mentioned as a proof of this Fault and its magnitude, that in sinking a well at Lenton House, 114 feet of Keuper was passed through, while a short distance to the north the Pebble Beds are exposed at the surface. This Fault has also been proved in the Clifton Colliery workings to be a downthrow to the south of 95 yards. Two smaller Faults are found in the Clifton Colliery-workings striking in a northerly direction from the larger one. The one on the west side of the pit is a downthrow to the west of 8 yards, the other on the east of Wilford Church is a downthrow of 11 yards to the east. Neither of these two Faults is known to affect the overlying Triassic rocks.

It has been before stated that there is a Fault of considerable size on the south side of Highfield House; its exact direction is not quite clear, but it runs between the house and the cliff of Bunter Pebble Beds; it has a downthrow to the north, and may join the other large Fault on the north side of Highfield House before it reaches the Clifton Colliery-workings, as no such Fault has been met with there.

The Fault marked on the map (71 S.E.) south of Bramcote is also a large one, throwing down to the south the Upper Keuper Marls against the Bunter Pebble Beds. For some part of its course from Bramcote Grove eastward, this Fault is distinctly traceable across the fields by the contrast of the soils, the sudden change from a sandy to a clayey soil being very marked; but on the north-west side of Beeston a considerable thickness of superficial gravel obscures the solid geology and renders the farther tracing of this Fault by any indications on the surface impossible. As it is known that the Pebble Beds underlie the gravel on the N.E. side of Beeston, this Fault may not continue in the same direct line as before, and it is possible it is shifted farther southwards by the north and south Fault that runs on the east side of Belle-vue. To what extent this shift may be is uncertain, but it is probably the same Fault that is supposed to occur somewhere between the Clifton Colliery and a bore hole made about a

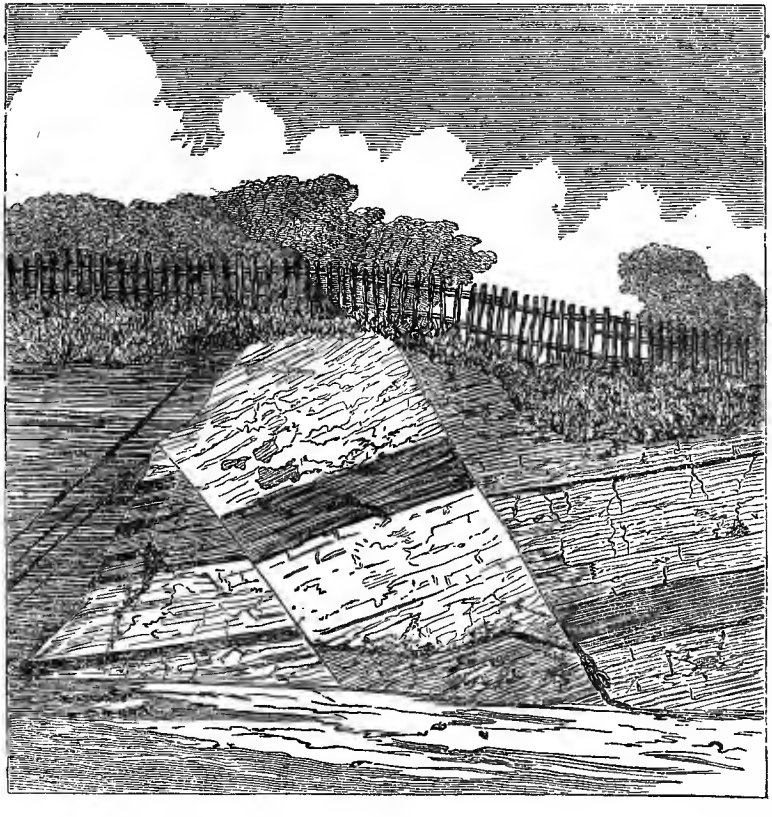
mile and a quarter to the south: the shift may be of such extent that it passes on the south side of Beeston instead of the north. On the west side of Bramcote Grove this Fault bends to the north-west towards Stapleford (One-inch map, 71 S.W.), where it brings the Coal-measure against the Pebble Beds.

The north and south, or Belle-vue Fault mentioned above, is inferred, in consequence of the Belle Vue Waterstone outlier being apparently suddenly cut off on the east side. This Fault has a downthrow to the west.

The course of the Fault east of Belle Vue (marked on the map by a curved and broken line) is very obscure, the ground being much covered by gravel; but the Waterstones, which are supposed to lie below the red clay soil of the large nursery gardens, are on a lower level than the Pebble Beds on the south-west side. This Fault may be a continuation of the Highfield House Fault, which has a downthrow northwards.

The Faults on the east side of Nottingham, now accurately laid down on the new edition of the map from observations made by Mr. Shipman, were exposed to view either in road or sewer-cuttings, but are now, or will be very shortly, built over. The woodcut below is from a sketch by Mr. Shipman, of a section on Blue Bell Hill road showing one of these Faults.

Fig. 6.



While building operations were in progress Mr. Shipman had facilities for observing these Faults that it was not possible to obtain either before or since. The result of his observations were embodied in a paper read before the Nottingham Naturalists' Society in 1877. At the time of writing the south-westerly of the two main Faults which strike across the north-east side of Nottingham was exposed at only two spots, namely, in the cliff in Patchitt's Park at the words "Gallows Hill" on the map, and in a road section on Blue Bell Hill road (Fig. 6), but it was met with in excavations at several intermediate points, and at Sneinton Elements it brings down gypseous Upper Keuper Marls alongside the Waterstones. The north-easterly main Fault was not exposed in section further south than at the elbow turn in Carlton road and in a section in a street opposite, but it could be traced along Martin street, across the middle of Dame Agnes street, along the north side of the Reservoir, where it was well exposed during the lowering of Mapperley road, and again in the Mansfield road opposite the Grosvenor Hotel. The next Fault in importance is one that connects the two main Faults, and was met with in Brighton street and on Woodborough road, where it is still exposed, bringing down the Upper Keuper alongside the Waterstones at the Roman Catholic Chapel. The area enclosed by these Faults, however, is shattered and disturbed by a multitude of minor dislocations.

There is a good exposure of a Fault, bringing down the Upper Keuper Marls against the Waterstones in the fine section of the Keuper by the side of the Midland Railway north of Colwick.

PHYSICAL FEATURES.

That the physical features of a country are due in a great measure to the unequal denudation of the different geological formations is well exemplified in this district. Every valley, hill, or ridge is formed by the wearing away of the different formations in proportion to their various degrees of hardness. Sometimes they are worn back into cliffs or escarpments, with the harder beds on the top, as if they had once been sea-cliffs, and by the washing out of the soft beds at the bottom the top fell from want of support. The cliff was thus gradually carried back. This is the appearance presented by the Soft Red Sandstones and the Pebble Beds above them, as shown along the line of junction from Papplewick northward, the soft sandstone itself making a prominent feature above the softer Permian Marls. The whole once covered the harder beds of Magnesian Limestone, and has been denuded away, leaving only a few small patches or outliers. The part of the country round Hucknall and Linby must once have been a bay nearly surrounded by the sandstone hills. The

junction between the Coal formation and the Magnesian Limestone can also in places be traced by the escarpment formed by the harder beds of the latter on the softer ones of the former.*

Between Nottingham and Southwell the physical features are of a different kind. Here the softer beds form the highest ground, but these have been subjected to much denudation. The Upper Keuper Marls have been worn into numerous valleys, exposing the Waterstones, the sandstone of which being comparatively hard, has better resisted destruction. It has been before noticed that in the deep dingles above Lambley the streams run on the top beds of the Waterstones, having cut through the softer beds above them.

The river Trent flows through a broad valley, cut in the Upper Keuper Marls, having for its base the Waterstones, which are covered by the re-arranged sand, gravel, and alluvial silt.

* Twenty years of observation, since the above was written, would incline me now to place more stress on subaerial denudation than on marine (1880). I believe that whatever may have been the first denuding agent, subaerial agencies have given the finishing touches to the moulding of the physical features of the district, as we now see them; and that the striking pillar of rock, the "Himlack stone," has slowly worn into its present shape after the country was raised above the sea for the last time.

"Himlack Stone," near Nottingham.

APPENDIX.

LIST OF WORKS ON THE GEOLOGY OF NOTTINGHAMSHIRE.

By W. WHITAKER, B.A., F.G.S.

1. GEOLOGICAL SURVEY PUBLICATIONS.

Sheets of the Map, Scale an inch to the mile.

71, S.W. (very small part at N.E. corner). By *E. Hull*, 1855.

71, S.E. (all but S. part). By *E. Hull*, 1855.

71, N.W. (E. edge). By *W. W. Smyth*, *A. C. Ramsay*, and *E. Hull*, 1855. Additions by *A. H. Green* and *J. R. Dakyns*, 1867.

71, N.E. By *W. T. Aveline*, *E. Hull*, and *T. R. Polwhele*, 1858. Additions and corrections by *W. T. Aveline*, 1879.

82. S.W. (S.E. corner). By *W. W. Smyth* and *J. Phillips*, 1852. Additions by *J. R. Dakyns*, 1866.

82, S.E. (all but N.W. part). By *W. T. Aveline* and *T. R. Polwhele*, 1858.

82, N.E. (E. half). By *W. T. Aveline*, 1861. Additions by *A. H. Green* and *T. V. Holmes*, 1875.

87, S.E. (S.E. corner). By *W. T. Aveline*, 1863.

Sheets of Horizontal Sections.

60. No. 1. From West to East, Crossing . . . . . the Magnesian Limestone and New Red Sandstone of Kirkby Moorside and Kirkby Forest. No. 2. S.S.W. to N.N.E. . . . . to the Magnesian Limestone and New Red Sandstone of Robin Hood's Hills, Nottinghamshire. By *E. Hull*, 1860.

61. No. 1. W. to E. . . . . across . . . . the Magnesian Limestone, and the New Red Sandstone and Marl, to Toot Hill south of Bingham. No. 2. W. to E. . . . . across the Magnesian Limestone, New Red Sandstone & Marl to the Wind Mill 3½ miles east of Ollerton. By *W. T. Aveline*, 1861.

Memoirs.

The Triassic and Permian Rocks of the Midland Counties of England. By *E. Hull*, 1869.

The Geology of the Country around Nottingham (71, N.E.). By *W. T. Aveline*, 1861.

The Geology of Parts of Nottinghamshire and Derbyshire (82, S.E.). By *W. T. Aveline*, 1861.

The Geology of Parts of Nottinghamshire, Yorkshire, and Derbyshire (82, N.E.). By *W. T. Aveline*, 1861.

2. LIST OF BOOKS AND PAPERS, CHRONOLOGICALLY ARRANGED.

1719.

Stukely. Dr. W. An Account of the Impression of the almost Entire Skeleton of a large Animal in a very hard Stone . . . . from Nottinghamshire.—*Phil. Trans.*, vol. xxx., no. 360, p. 693.

1740.

Short, Dr. T. An Essay Towards A Natural, Experimental, and Medicinal History of the Principle Mineral Waters of . . . . . Nottinghamshire . . . . . 4to., *Sheffield.*

1799.

Tennant, S. On different Sorts of Lime used in Agriculture.—*Phil. Mag.*, vol. v., p. 209.

1810.

Farey, J. A List of about Five Hundred Collieries in and near to Derbyshire.—*Phil. Mag.*, vol. xxxv., p. 431.

1814.

Toplis, Rev. —. Basaltic Rock near Nottingham.—*Annals of Philosophy*, vol. iii., p. 314.

1816-1818.

Sowerby, J. The Mineral Conchology of Great Britain, vol. ii. 8vo., *London.* (Nottinghamshire, p. 124).

1829.

Sedgwick, Rev. Prof. A. On the Geological Relations and internal Structure of the Magnesian Limestone, and the lower Portions of the New Red Sandstone Series in their Range through Nottinghamshire . . . . ., &c.—*Trans. Geol. Soc.* ser. 2, vol. iii., pp. 37, 239. Long abstract in *Proc. Geol. Soc.*, vol. i., p. 63 (1827).

1834.

Conybeare, Rev. W. D. On the probable future Extension of the Coal-fields at present worked.—*Phil. Mag.*, ser. 3, vol. iv., p. 346 (Nottinghamshire, p. 347).

1837.

Hopkins, W. On certain points in Physical Geology.—*Rep. Brit. Assoc.* for 1836, *Sections*, p. 78.

1841.

Bailey, T. On the Gravel Deposits in the Neighbourhood of Basford.—*Proc. Geol. Soc.*, vol. iii., p. 411.

1843.

Daubeny, Dr. [C.]. On the Causes of the Irregularities of Surface which are observable in certain parts of the Magnesian Limestone Formations of this Country.—*Rep. Brit. Assoc.* for 1842, *Sections*, p. 39.

1844.

Smith, C. H. Lithology, or Observations on Stone used in Building. Treating chiefly of the Magnesian Limestones of Yorkshire, Derbyshire, and Nottingham. —(*R. Inst. Brit. Architects*). 4to. *London.*

1853.

Strickland, H. E. On Pseudomorphous Crystals of Chloride of Sodium in Keuper Sandstone.—*Quart. Journ. Geol, Soc.*, vol. ix., p. 5.

Thorpe, Rev. W. On the Diluvial and Gravel Beds of Yorkshire and Nottinghamshire.—*Pro. Geol. Polytech. Soc., W. Riding, York*, vol. iii., p. 244.

1857.

Fairbairn, W.—On the Comparative Value of various kinds of Stone, as Exhibited by their Powers of Resisting Compression.—*Mem. Lit. Phil. Soc. Manchester*, ser. 2, vol. xiv., p. 31.

1860.

Lancaster, J., and *C. C. Wright.* On the Sinking of Shireoak Colliery. Worksop . . . . . .—*Quart. Journ. Geol. Soc.*, vol. xvi., p. 137.

1861.

Drake, F. Human Remains found with the Bones of Extinct Animals in the Vale of Belvoir.—*Geologist*, vol. iv., p. 246. [This and the following really refer to the Valley of the Trent.]

——— Human Remains in the Drift of the Vale of Belvoir (Muskham, near Newark on Trent).—*Ibid.*, p. 349. See also a letter on the above by *J. H. W.*, p. 415.

——— Human Remains in the Valley of the Trent, *Ibid.*, p. 495.

Tookey, C. (Analysis of Nottinghamshire Coal) in Dr. J. Percy's "Metallurgy. Fuel, Fire-clays &c." 8vo. *London.*

1862.

Anon. Particulars of the Strata sunk through at High Park Colliery, in the Parish of Greatley, in the County of Nottingham.—*Geologist*, vol. v., p. 414.

Blake, C. C. On the Crania of the most ancient Races of Men.—*Ibid.*, p. 205. (Refers to the Muskham skull).

Smith, C. F. S. On the Winning and Working of Cinderhill Colliery, near Nottingham.—*Trans. N. Inst. Min. Eng.*, vol. x., p. 149.

Woodhouse, J. T. On the Progress of Coal Mining in the Counties of Derby and Nottingham, ... &c.—*Ibid.*, pp. 117, 137.

1864.

Hedley [*E.*?] On the Long Wall System.—*Trans. S. Wales Inst. Eng.*, vol. iii., p. 148.

1866.

Stevenson, W. The building Materials of Nottinghamshire; being a series of practical Essays illustrating the Geological . . . . hearings. Republished from the *Building News*, with additional notes. 8vo. *London* and *Nottingham.*

1867.

Hedley, E. On the Sinking of Anneraley Colliery.—(*Brit. Assoc.*)—*Geol. Nat. Hist. Repertory*, vol. i., p. 339.

Murchison, Sir R. I. On the parts of England and Wales in which Coal may and may not be looked for beyond the known Coal-fields.—*Rep. Brit. Assoc.* for 1866, *Sections*, p. 57.

1868.

Wilson, E. On Faults and Contortions in Strata (section near Nottingham). — *Geol. Mag.*, vol. v., p. 341.

1869.

Jenkins H. M. Note on the Geology, in H. H. Dixon's "Report on Nottinghamshire Farming."—*Journ. R. Agric. Soc.*, ser. 2, vol. v., p. 449.

1871.

Report of the Commissioners appointed to inquire into the several matters relating to Coal in the United Kingdom. Vol. i. General Report and Twenty-two Sub-reports—Fol. *London.*

1872.

Lewis, H. On the Method of Working Coal by Long-wall, at Annesley Colliery, Nottinghamshire (gives a section of the Top Hard Coal.)—*Trans. N. Engl. Inst. Eng.*, vol. xxi., p. 3.

1873.

Weston, W.—On the Winning and Working of High Park Colliery, Notts. —*Trans. Chesterfield Inst. Eng.*, vol. ii., p. 96, pls. x., xiii. (section).

1874.

Irving, Rev. A. On the Geology of the Nottingham District.—*Geol. Mag.*, dec. ii., vol. i., p. 314.

1875.

Anon. Lincolnshire or East Nottinghamshire Coal exploration.—*Colliery Guardian*, vol. xxx., p. 265.

Brodie, Rev. P. B. On the Lower Lias at Eatington and Kineton, and on the Rhætics in that neighbourhood, and their further extension in Leicestershire, Nottinghamshire, ... &c.—39 *Ann. Rep. Warwicksh. Nat. Hist. Soc.*, p. 6. See also *Rep. Brit. Assoc.* for 1875, *Sections*, p. 64.

Irving Rev. A. On the Geology of the Nottingham District.—*Proc. Geol. Assoc.*, vol. iv., no. 1, p. 45.

Tylden-Wright, C. The Geology of Sherwood Forest and the District. Chap. xvi. of R. White's "Worksop, "The Dukery," and Sherwood Forest." 8vo. *Lond.* and *Worksop.*

1876.

Anon. Lincolnshire or East Notts Coal Exploration.—*Colliery Guardian*, vol. xxxi., p. 136.

Binney, E. W. On some Bronze Coins found sixty years ago under a Peat Bog at Misterton Car, in Notts.—*Proc. Lit. Phil. Soc. Manchester*, vol. xv., p. 5.

Harrison, W. J. Notes on the Geology of the North Midland Counties, in Kelly's Post Office Directory for Notts, &c. 4to. *Lond.*

Irving, Rev. A. Some Recent Sections near Nottingham.—*Quart. Journ. Geol. Soc.*, vol. xxxii., p. 513.

———— Report of Excursion to Grantham and Nottingham.—*Proc. Geol. Assoc.*, vol. iv., no. 8, p. 491.

Wilson, E. On the Permians of the North-East of England (at their Southern Margin) and their Relations to the under- and overlying Formations —*Quart. Journ. Geol. Soc.*, vol. xxxii., p. 533.

1877.

Anon. Discovery of Coal [Pleasley].—*Colliery Guardian*, vol. xxxiii., p. 292.

Aveline, W. T. The Magnesian Limestone and New Red Sandstone in the Neighbourhood of Nottingham.—*Geol. Mag.*, dec. ii., vol. iv., pp. 155, 380.

De Rance, C. E. Second Report of the Committee for investigating the circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England . . . . . &c.—*Rep. Brit. Assoc.* for 1866, p. 95. (Nottinghamshire, pp. 97, 98, 108.)

Shipman, J. Conglomerate at the Base of the Lower Keuper.—*Geol. Mag.*, dec. ii., vol. iv., p. 497.

Wilson, E. The Magnesian Limestone and New Red Sandstone in the Neighbourhood of Nottingham.—*Ibid.*, p. 328.

1878.

Jennings, J. H. On the Origin of a Quartzite Boulder from the Bunter Conglomerate, Nottingham.—*Geol. Mag.*, dec. ii., vol. v., p. 239.

Shipman, J. Some New Features in the Geology of East Nottingham.— *Midland Naturalist*, vol. i., pp. 18, 30.

1879.

Wilson, E. The Age of the "Pennine Chain."—*Geol. Mag.*, dec. ii., vol. vi., p. 500. (*Brit. Assoc.*)

Wilson, E. and *J. Shipman.* On the Occurrence of the Keuper Basement Beds in the Neighbourhood of Nottingham.—*Ibid.*, p. 532.

1880.

Shipman, J. Notes on the Alluvial & Drift Deposits of the Trent Valley near Nottingham. Pp. iv., 20, 8vo. *Nottingham.* Reprinted, with additions, from *Ann. Rep. Nottingham Nat. Soc.*

Wilson, E. The Age of the Penine Chain. *Midland Naturalist*, vol. iii., p. 1.

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